Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 1: Executive Summary

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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The author for this document is Ralph Gunness, assisted and reviewed by Chris Way (CEO), Dr Bob Cook, Barry Smith, Cameron Fink, Bradley Stout, Ben Hamilton, Andre Coffee, Chris Thompson, and Trudy Bretherton.

1.0 Executive Summary

The Moonie Oil Field is the oldest Queensland oil field and with reducing oil recovery volumes. Enhanced Oil Recovery (EOR) is a recognised petroleum activity for the purpose of extending oil recovery while at the same time sequestering 80% of the injected CO_2. In the full-scale project this will be 100% CO_2 sequestration.

Australia on any day has a National long term diesel supply deficit. Bridgeport Energy supplies petroleum products which support the inland heavy transport industry (as one of the only Australian suppliers other than importing), with no export overseas.

This Environmental Authority (EPPG03516215) amendment is submitted by Bridgeport (Surat Basin) Pty Ltd (ACN: 608515939) a wholly owned subsidiary of Bridgeport Energy Limited, who is the holder and operator of the PL 1 Moonie Oil Field.

The amendment includes the injection of 120,000 tonnes of CO_2 p.a. for eight years, from industrial scale CO_2 generators like the Millmerran Power Station. Without this EOR project this volume would otherwise be released to atmosphere. The composition of the Millmerran CO_2 stream is detailed in Chapter 10.

This initial project is scheduled to run for a period of 8 years post commissioning.

1.2 An excellent location choice

The reasons why the Moonie Oil Field is an excellent choice for this initial project includes:

- It is in a geological anticlinal trap considered to be 90 Ma years old, with proven gas, oil, and water trap integrity (upper, lower, and horizontal seals).
- Average net thickness of the formation is sufficient to hold 60 MM tonnes of CO_2.
- Stable cratonic geological setting – low incidence of earthquake activity.
- Precipice oil reservoir is well isolated from shallower aquifers.
- Top impermeable seal consists of marine lacustrine shale and siltstone (20-80m thick) providing vertical closure (Rodger et al. 2019c).
- Moonie-Goondiwindi fault provides a lateral seal on the northwest flank.
- No further faulting has been observed seismically or through drilling operations.
- There is no evidence of vertical “gas chimneys” (survey completed by University of Queensland).
- The minerals, carbonates and clays present react and reform to a cementing seal when exposed to mild acid.
- Relevant existing well infrastructure in place with an experienced work force, and
- No significant impact to the receiving environment.

1.3 Supporting Document "Chapter" contents and organisation

This supporting document has 4 basic sections with attendant chapters they are,

1. **Background regional data and tenement information**,
   - Chapter 1: Executive Summary
   - Chapter 2: Regional Data and Background Information

2. **The initial project injection plan**
   - Chapter 3: Initial CO_2 Injection Plan
   - Chapter 4: Well Plug & Abandonment, Rehabilitation &Site Handover
   - Chapter 5: Monitoring Plan and Schedule

3. **The Physical Science discussions**
   - Chapter 6: Geology
   - Chapter 7: Hydrogeology
   - Chapter 8: Groundwater Geochemistry
   - Chapter 9: Predictive Reservoir Models and Petrophysics

4. **The environmental assessment of potential impacts**
   - Chapter 10: Assessment of Impact: Air
   - Chapter 11: Assessment of Impact: Geology and Geomorphology
   - Chapter 12: Assessment of Impact: Groundwater
   - Chapter 13: Assessment of Impact: Receiving Environment
   - Chapter 14: Assessment of Impact: CO_2 Operations
   - Chapter 15: Assessment of Impact: Noise
   - Chapter 16: Assessment of Impact: Terrestrial Ecology
   - Chapter 17: Assessment of Impact: Waste, and
   - Chapter 18: Assessment of Impact: Community & the Economic Benefit

1.4 Key Definitions

1.4.1 Geological Formation and Groundwater definitions,

- The “Precipice formation reservoir” is the main oil producing part of the larger Precipice aquifer in the Moonie field containing oil, water and solution gas. It exists within the Moonie anticline above the main Precipice Formation, and we refer to it as the Precipice “oily water leg”, with a unique water quality (see Chapters 6, 7 & 8),

- The “Precipice formation” is the tighter part of the formation underlying the Precipice formation reservoir or the Precipice “oily water leg” and is the main water bearing transition zone extending well below the Precipice “oily water leg” and we refer to it as the Precipice “main water leg”, and it also has a distinct water quality,

- “Evergreen formation” is the formation lying above the seal and the Precipice formation, which is principally water bearing, and it also has distinct water properties.

1.4.2 Supercritical Carbon Dioxide

- Supercritical Carbon Dioxide ($scCO_2$) is defined as a physical state of liquid $CO_{2,}$ whereby the CO_2 can be in a liquid or in the gas phase. This condition is governed by Temperature and Pressure. The following graph Figure 1 illustrates the temperature and pressure at which CO_2 becomes supercritical. See the Critical point at the intersection of 68 bar (pressure) and 31.5°C (temperature).

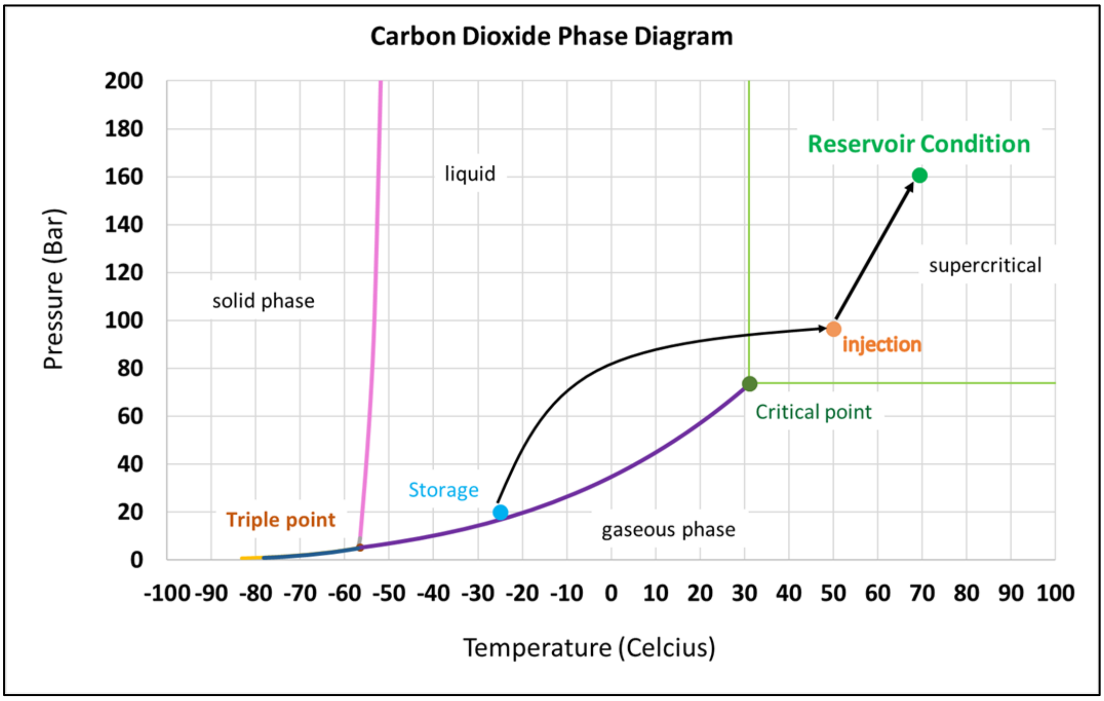

Figure 1, Phase diagram of CO_2 and Supercritical CO_2

For reference purposes a general summary of the **Moonie Oil Field Reservoir Parameters** is detailed in Table 1-1 overpage and is used throughout this Amendment Application.

1.5 Principle References

The principle external references used in the compilation of this supporting document are from the University of Queensland Surat Deep Aquifer Project (UQ-SDAAP) and Professor Andrew (Alf) Gannett and include:

- Scoping study for material carbon abatement via carbon capture and storage, UQ-SDAAP Project Report, April 2019,
- Sequence stratigraphic analysis of the Lower Jurassic Precipice Sandstone and Evergreen Formation in the Surat Basin, Australia: Implications for the architecture of reservoirs and seals for CO2 storage, Wang etal 2019, Marine and Petroleum Geology 102 (2019) 829-843,
- Co2 water rock predictions from aquifer and oil field drill core data: The Precipice Sandstone – Evergreen Formation CO2 storage reservoir-seal pair, Pearce etal 2019, Australian Exploration Geoscience Conference 2019

Table 1-1, Moonie Oil Reservoir Statistics "at a glance"

Moonie Oil Reservoir Statistics, at a Glance.					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Reservoir Stats					
Original Precipice Oily Water Leg Reservoir Pressure (1,515m)	17,450	2,530			
Current Precipice Oily Water Leg Reservoir Pressure (1,515m)	16,550	2,400			
Formation Slip Pressure					
Slip Pressure (P90=53,150kpa, mean 57,250 kPa)	51,700	7,498			
Formation Seals					
Seal thickness					20-100
Reservoir Fracture Seal Pressure	52,170	7,565			
Permeability - ultimate seal core plugs			0.003 - 0.086 av 0.037		
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809			
Bottom Hole Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712			
Permeability					
Bulk Permeability Precipice main water leg Horizontal, mean			580		
Precipice main water leg Horizontal, mean			127		
Ultimate Seal			0.003 - 0.086 av 0.037		
Pore Throat measurements					
Precipice M38					0.01 - 100 µm
Porosity					
Evergreen				13	

Moonie Oil Reservoir Statistics, at a Glance.					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Precipice (average Sandstone)				16.8	
Injection Pressure Thresholds					
Gravity Head of the injecting fluid ($scCO_2$) - density of 480kg/m^3	7,172	1,040			
Friction Loss of injecting	689	100			
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809			
Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712			
Miscibility * depends on temperature $scCO_2$ pressure range	>11,380	>1,605			
Estimated Injection pressure range, depends on temperature, mass, density	>11,380 to 39,388	>1,605 to 5,712			
Recommended Pressure Alarm Settings					
WHP High Pressure Alarm setting, *subject to design calculations, i.e., below tubing and packer yield pressures	39,388* Final depends on additional factors	5,712* Final depends on additional factors			

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Chapter 2: Regional Data and Background Information

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2.0 Executive Summary

The Moonie Oil Field is the oldest commercial oil field in Australia and has depleting oil recovery volumes. Enhanced Oil Recovery (EOR) is a recognised petroleum activity for the purpose of enhancing further oil recovery while at the same time in this initial project sequestering 80% of the injected CO_2. Subject to an economic review in 1st quarter of year 4, 100% sequestration with full recycle of CO_2 will be considered.

The following Chapter outlines the background information related to the project and the amendment application.

2.1 Introduction

In 2009, Bridgeport Energy Limited was formed as an independent Australian oil and gas exploration and production company. The corporate objective is to acquire and optimise exploration and production assets adding value for shareholders and for the State of Queensland. The company was acquired in 2013 by New Hope Corporation Limited and has continued to grow with interests in 12 producing oil fields operating across 15,000 km² of onshore petroleum tenements in the Surat, Cooper-Eromanga and Otway basins.

Bridgeport (Surat Basin) Pty Ltd (ACN: 608515939) is a wholly owned subsidiary of Bridgeport Energy Limited and is the holder and operator of the "brownfield" PL 1 Moonie Oil Field (Environmental Authority EPPG03516215 (the EA)). Bridgeport proposes an amendment to the EA to authorise the injection of up to 1 million tonnes of CO_2 (super critical Carbon Dioxide) into the BEL Enhanced Oil Recovery (EOR) injection initiation activity within the project area. The project surface area is 2 hectares (ha) encompassing Moonie 27 within the existing Petroleum Lease PL 1, comprising approximately 192 ha.

The PL 1 EA permits low impact activities such as exploration and oil extraction within the tenement area. PL 1 was the first oil extraction environmental authority in Queensland and the reserves have been depleting over several decades.

The proposed CO_2 EOR injection process at Moonie Oil Field by Bridgeport Energy is estimated to cost more than $15 million and will initially utilise CO_2 separated from thermal coal power plant emissions at Millmerran, QLD and elsewhere as needed. This will provide a cost effective, safe and international industry-recognised process to quickly and effectively remove gross volumes of carbon from the atmosphere. The injection of CO_2 is the means of extracting incremental volumes of oil from the rock formations while providing the additional positive environmental gain of sequestering carbon.

This minor EOR amendment activity of injecting CO_2 into the mature sealed Moonie Oil Field will assist Australia (and Queensland) in a small way to meet its Paris Environmental agreement commitments while at the same time aiding in the extraction of oil to meet current and growing requirements for Australian sourced crude oil and its by-products for the Australian domestic market.

This document has been prepared to support this activity as "a minor amendment" of the site-specific Environmental Authority in accordance with the relevant provisions of the Environmental Protection Act and Regulations (Qld, EP Act, 1994) and the Petroleum and Gas Act and Regulations.

The injection of CO_2 will also fully comply with the original lease permit, i.e., "the lessee shall work the land in accordance with recognised good oil field practice as accepted in the USA.". CO_2 EOR injection has matured as a technology and has been progressively accepted as good oilfield practice in the USA and elsewhere, since the 1970's. In 2014, there were approximately 123 CO_2 EOR projects in operation around the World accounting for approximately 6% of total world oil production.[1] In Australia active industrial scale injection of CO_2 occurs at the Gorgon project and in South Australia Santos is nearing FID on its Moomba CO_2 project expected to start injection in the mid 2020's. There are test facility sites active in Victoria at the state government owned Carbon Net in the Latrobe valley and the CO_2CRC site in the Otway, whilst CINSW is actively testing CCS sites in NSW and CTSCo testing its CCS site in Queensland. This Moonie project will be the first in Queensland and will initially use anthropogenic CO_2 from a privately owned thermal coal fired power plant at Millmerran.

2.1.1 Supporting Information Report

This supporting information document has been prepared to accompany an application for an amendment to the Environmental Authority (EA) EPPG03516215 under section 224 of the Environmental Protection Act 1994 (EP Act). This second amendment application relates to the existing PL1 EA and comprises the following documents:

- Cover letter,
- Completed DES application form, and
- Supporting information report (this document).

2.2 Scope of the document

This EA amendment relates only to the new EOR activities detailed in the minor amendment proposal detailed above. The following information detailed below satisfies Section 226 & 227 of the EP Act, including the following:

The description of the proposed project amendment (above),

This amendment application does not relate to a new petroleum lease,

No new tenure applications are required for the Project and the following existing documents will prevail:

- A discussion of the relevant sections of the EP Act in relation to the EA amendment process,
- A description of the petroleum tenure and activities, and a general description of the environmental impact by the proponent,
- A description of the environmental values for air, land, noise, vibration, community, cultural heritage, groundwater, and waste management,
- A risk assessment of these environmental aspects with an assessment of the environmental impact (if any) by the project proposal,
- A description of the controls, monitoring, contingency plans, and continual improvement, and
- Details of the applicable rehabilitation and decommissioning activities.

[1] *Carbon Dioxide Enhanced Oil Recovery: Industrial CO_2 Supply Crucial For EOR, By Michael L. Godec, The American Oil & Gas Reporter, February 2014 Editor's Choice.*

2.3 Details of the proponent

Bridgeport (Surat Basin) Pty Ltd is the holder and operator of the PL 1 EA and is the Registered Suitable Operator (reference: RSO: 000389) in accordance with the Department of Environment and Science (DES) suitable operator register, required by the EP Act.

2.3.1 Resource Authority and Ownership details

This amended application relates to an existing EA for a resource project. All the activities located within the amended application are carried out as a single operation. The following Table 2-1 details the current authorities and ownership details.

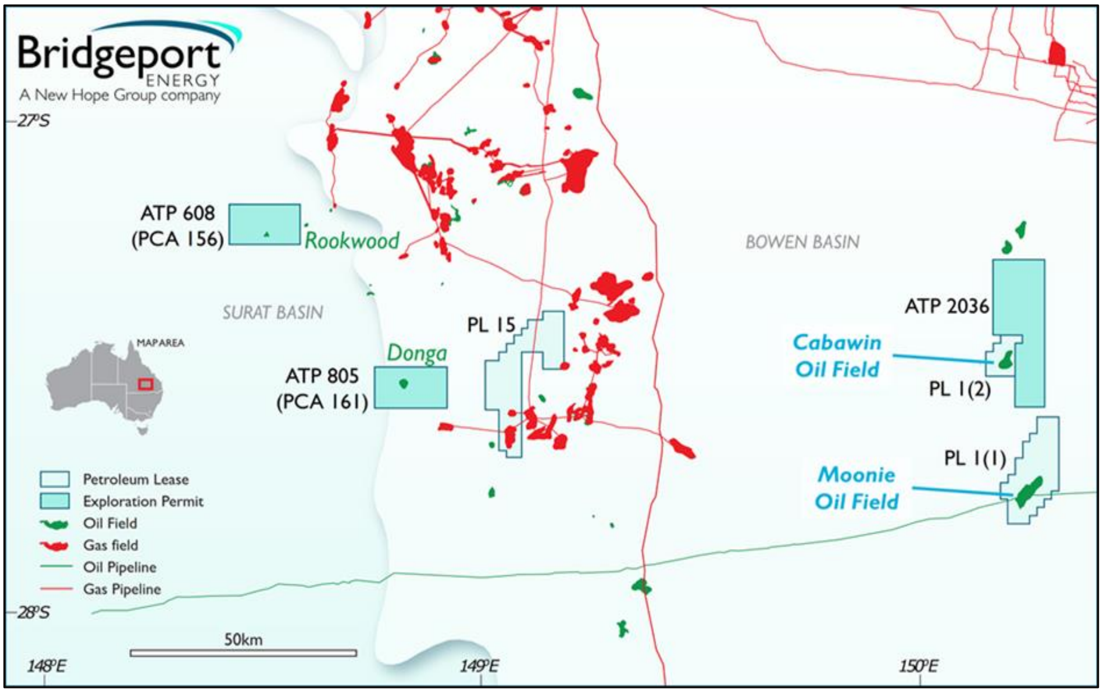
Table 2-1 Moonie Oil Field current authorities and details

Project Tenement	Current Registered Title Holder
PL 1 Environmental Authority EPPG03516215	Bridgeport (Surat Basin) Pty Ltd (ACN: 608515939) a wholly owned subsidiary of Bridgeport Energy Limited is the holder and operator of the PL 1 Moonie Oil Field

2.4 Location of the Initial Injection Project

The Moonie Oil Field (PL 1) is situated 11 km to the west of the town of Moonie located in the Southwestern Darling Downs in PL 1(1) in the Darling Downs Regional Council local government region of Queensland being 27.65 S and 149.15 E (see Figure 2-1, below). The tenement comprises 192 ha in the southwestern Surat Basin referred to in Figure 2-1 below.

Figure 2-1 Location Map of Moonie Field



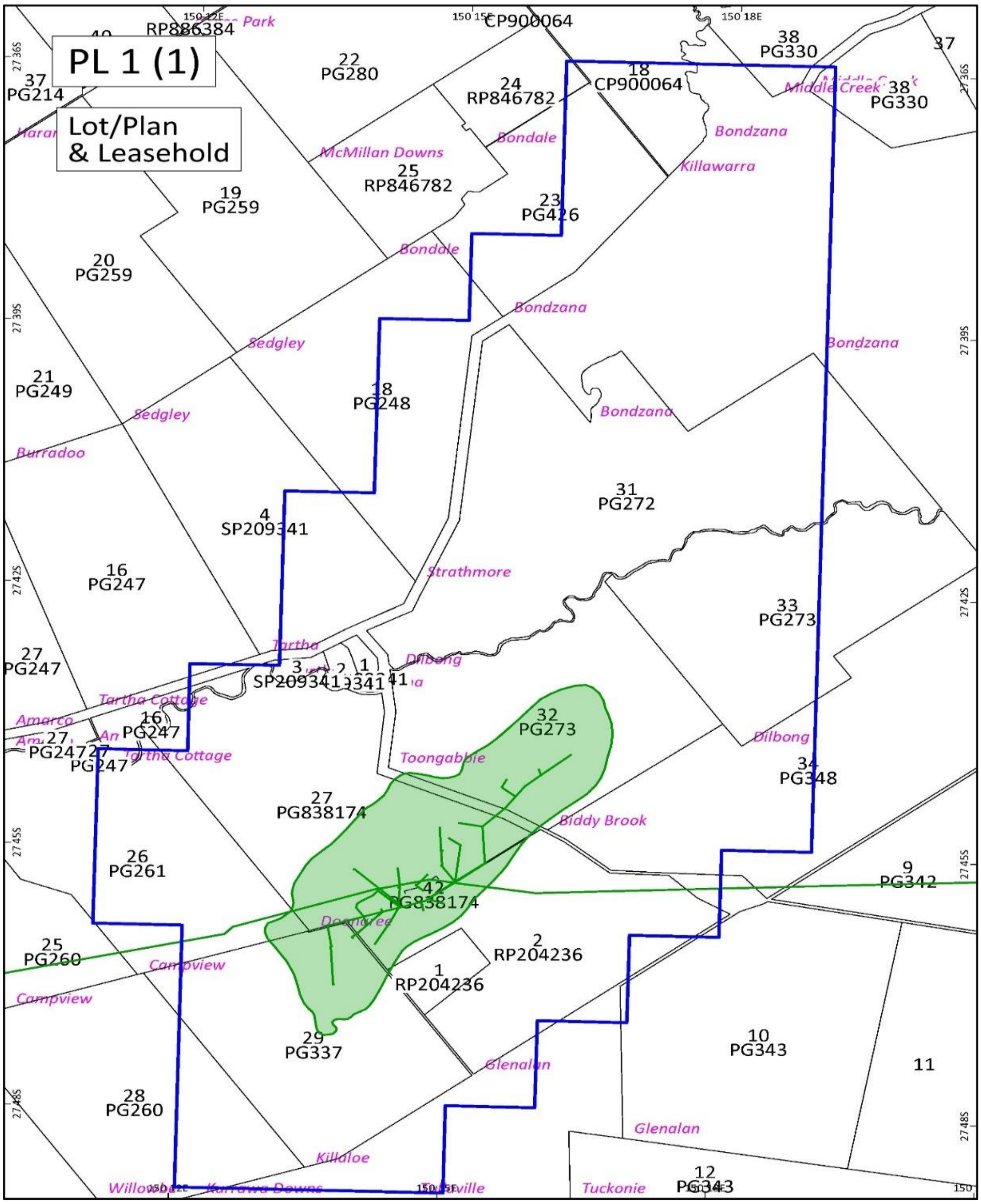
2-5 Real Property Description & Landholders.

The most central real property description data is Lot 42, PG 838174 and is illustrated in Figure 2-3 below. The greater project area is owned by 4 landholders (areas 34, 32, 29, 27 and 2 below) and a portion (areas 1 and 42 below) owned by Bridgeport.

Bridgeport has Conduct and Compensation Agreements with all landholders. Bridgeport has a Cultural Heritage Management Plan (CHMP) in place with the Bigambul People.

Figure 2-2, The PL1 Moonie Oil Field Plan of Lot and Leasehold Property data is illustrated below.

Figure 2-2 Map of Lot and Plan Numbers for PL1 Moonie



2-6 Local Land use

The surrounding land use consists of mixed dryland cropping and livestock production (classified as Rural). The project area has been cleared and farmed for approximately 150 years. Dwellings are widely distributed across the project area. To the south and east of the central production facility is dry land cropping and to the north, west and south-east is livestock fattening.

2.7 The Moonie Oil Field existing operations and infrastructure location

A total of 46 wells have been drilled in this field of which 12 have been plugged and abandoned thus far. There are currently 12 wells on production (May 2020) with a number awaiting routine workovers. Moonie 1-18 were drilled before the start of production and Moonie 19 onwards were drilled after production had begun.

Currently at Moonie there are 34 available oil wells located across approximately 192 ha, the location of the injection well is considered in Table 2-3 below. The wells are connected by surface flow lines leading to oil separators, oil storage tanks and a crude oil load out facility. Of these 34 wells a recent study by the University of Queensland identified a cluster of 5 wells located around the prime injection well (Moonie 27) forming the basis of the CO_2 Initial Injection Project. The location and general configuration of the wells is illustrated in Figure 2-3 below, "Aerial photo of the Moonie Oil Field and location of Moonie 27 (M27)". With the full field layout in Figure 2-4.

Separated formation water is directed to a series of evaporation ponds illustrated in Figure 2-3. Other supporting infrastructure consists of a central processing plant, storage tanks, operator accommodation, workshops, laydown areas, telecommunications, and office facilities.

Figure 2-3 Aerial Photo of the Moonie Field and the location of Moonie 27

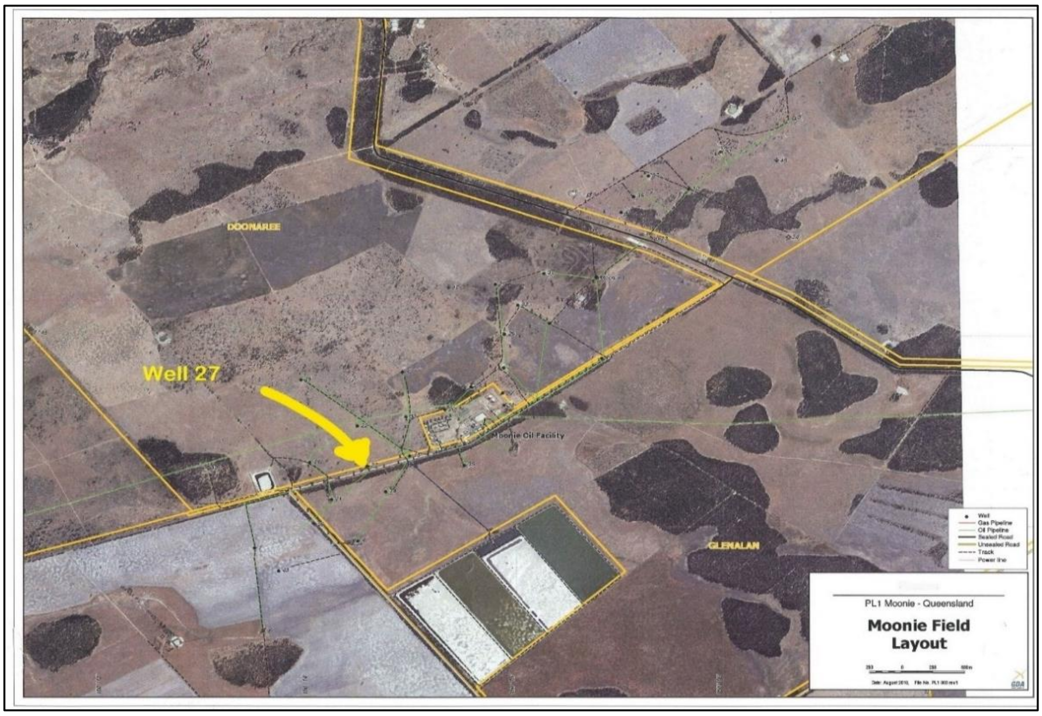


Figure 2-4 The Moonie Oil Field Map with the location of Moonie 27 highlighted.

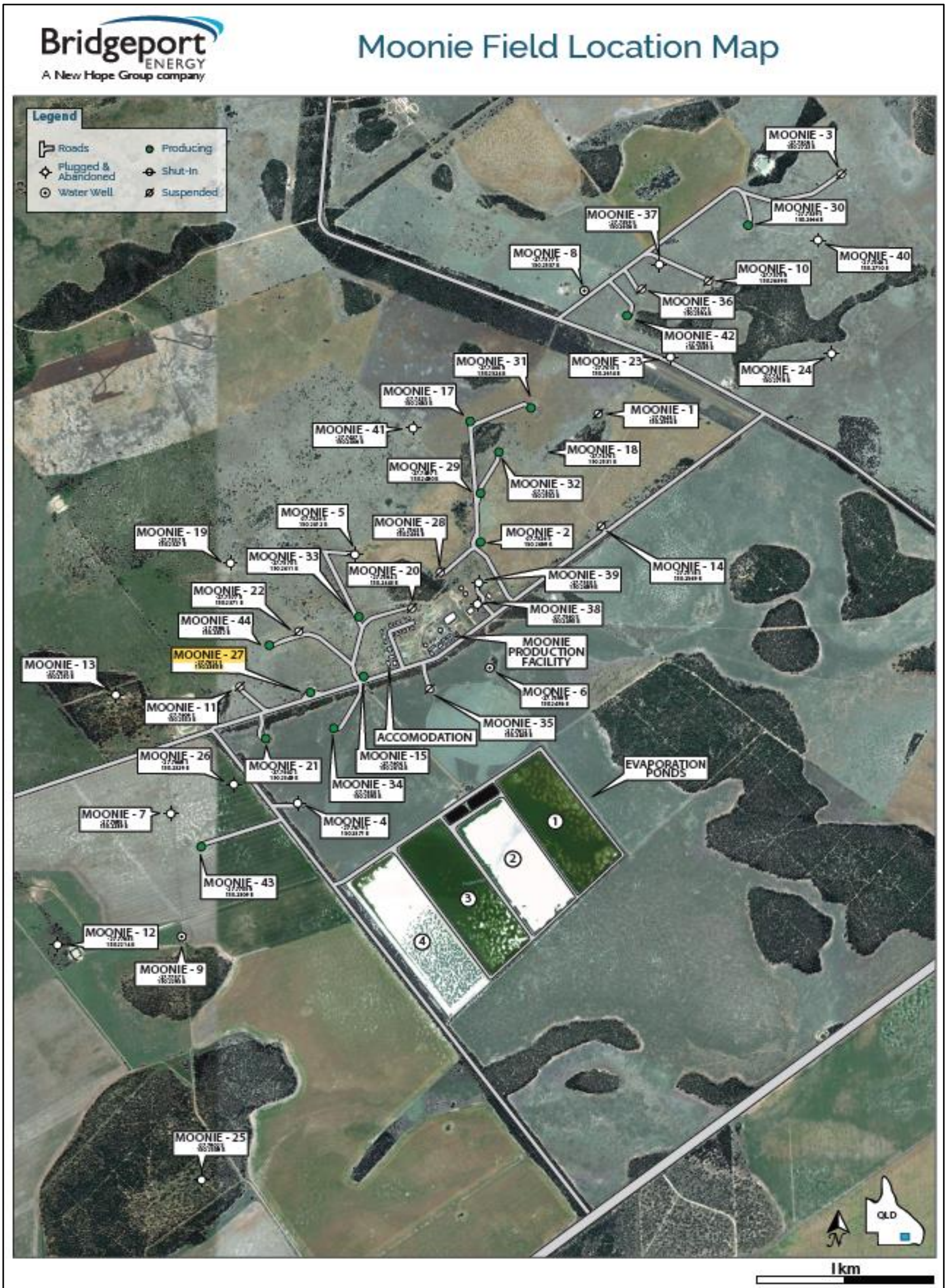


Table 2-2 overpage details the current status of each well.

Table 2-2 The status of the Moonie Oil Field Wells

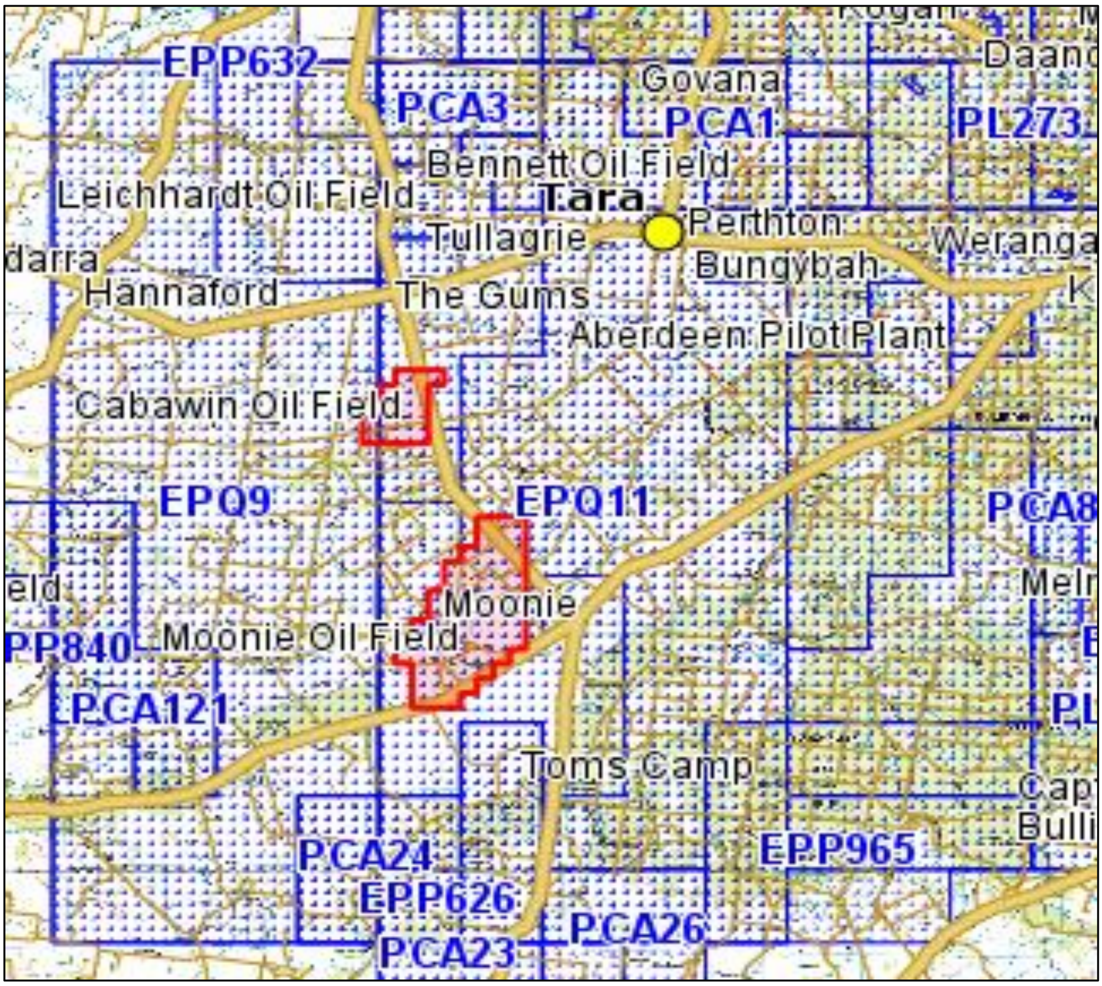
Well Name	Formation	Status	AL Type	Comments
Moonie-1	Evergreen	Suspended	ESP	
	Precipice	Suspended	ESP	
Moonie-2	Evergreen	Online	ESP	
	Precipice	Online	ESP	
Moonie-3	Precipice	Suspended	-	
Moonie-4	Precipice	Shut in	ESP	
Moonie-5	-	P&A	-	
Moonie-6	-	Water well	-	
Moonie-7	-	P&A	-	
Moonie-8	-	Water well	-	
Moonie-9	-	Water well	-	
Moonie-10	Precipice	Suspended	-	
Moonie-11	Precipice	Suspended	-	
Moonie-12	-	P&A	-	
Moonie-13	-	P&A	-	
Moonie-14	Evergreen	Shut in	-	Rod String still downhole
	Precipice	Plugged	-	
Moonie-15	Precipice	Online	ESP	
Moonie-16	-	Water well	-	
Moonie-17	Evergreen	P&A	-	
	Precipice	Shut in	Beam pump	
Moonie-18	Evergreen	Shut in	ESP	
	Precipice	Shut in	ESP	
Moonie-19	-	P&A	-	
Moonie-20	Evergreen	Suspended	-	
	Precipice	Suspended	-	
Moonie-21	Evergreen	Online	ESP	
	Precipice	Online	ESP	
Moonie-22	Precipice	Suspended	-	
Moonie-23	-	P&A	-	
Moonie-24	-	P&A	-	
Moonie-25	-	P&A	-	
Moonie-26	-	P&A	-	

Well Name	Formation	Status	AL Type	Comments
Moonie-27	Precipice	Shut in	Beam pump	
Moonie-28	Evergreen	Suspended	-	Kill string downhole
	Precipice	Plugged	-	
Moonie-29	Precipice	Online	ESP	
Moonie-30	Precipice	Online	Beam pump	
Moonie-31	Precipice	Online	ESP	
Moonie-32	Evergreen	Online	ESP	
	Precipice	Online	ESP	
Moonie-33	Precipice	Shut-in	ESP	
Moonie-34	Evergreen	Online	ESP	
	Precipice	Online	ESP	
Moonie-35	Precipice	Suspended	-	
Moonie-36	Precipice	Suspended	-	
Moonie-37	Evergreen	Shut in	ESP	
	Precipice	Shut in	ESP	
Moonie-38	-	Junked	-	
Moonie-39	Evergreen	Suspended	-	
Moonie-40	-	P&A	-	
Moonie-41	-	P&A	-	
Moonie-42	Precipice	Online	Beam pump	
Moonie-43	Precipice	Online	ESP	
Moonie-44	Precipice	Online	ESP	
Moonie-45	Precipice	Shut in	-	
Moonie-46	Precipice	Shut in	-	

2-8 Surrounding Resources Activity

The project area lies on the border of the significant coal seam gas (CSG) fields to the Northeast, North and Northwest. These CSG fields are at an average depth of 450-650m and are operated by Arrow, QGC and Origin. There are several exploration and evaluation tenures in the surrounding areas. Two disused pipeline licences are connected to Moonie, (the Moonie to Brisbane Pipeline (MBP) and the Jackson to Moonie Pipeline (JMP). The density of Petroleum and Gas activity is illustrated in Figure 2-5 below, the density of other resource users surrounding the Moonie Oil Field.

Figure 2-5 The density of Resource Activities in proximity to Moonie Oil Field



2-9 Climate of the Moonie Region

Moonie experiences a predominantly summer rainfall pattern. Goondiwindi Post Office is the closest location to the oilfield with long term records of rainfall. A summary of these records is illustrated in Table 2-3. The annual rainfall is between 200 and 622mm p.a.

Table 2-3 Rainfall records from the Goondiwindi Post Office 1879-1991.

Month	Mean	Decile 1	Median	Decile 9
January	789.5	16.3	64.7	161.5
February	69	9.4	52.8	140.8
March	59.5	4.3	39.8	134.8
April	38.7	1.5	26.4	89.2
May	42.9	3.9	33	92.4
June	40.6	5.6	29.5	96.5
July	41.9	4.9	35.5	89.8
August	33.1	4	26.7	66.4
September	39	2.3	33.9	87
October	48.7	10.7	42.6	96.3
November	59.8	10.9	48.2	119
December	69.8	12	61.4	132.9
Annual	621.6	411.7	607.8	865.1

Using a one-hundred-year sequence of monthly rainfall, monthly averages of incident daily radiation integral, mean daily temperature and evaporation was generated for Moonie and illustrated below in Table 2-4: Monthly Climate averages at Moonie over a 100-year period.

Table 2-4 The Moonie monthly climate averages over 100 years

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall (mm/month)											
86	64	51	34	36	31	45	41	54	59	60	73
Daily Radiation (MJ/m^2/day)											
24.3	22.7	20	16.7	13.5	12.1	12.4	15.1	18.3	22	24.8	25.6
Mean Daily Temperature (°C)											
23.9	23.4	22	19.9	17.8	16.3	15.6	16.2	17.6	19.7	21.8	23.3
Evaporation (mm/day)											
7.4	6.6	5.4	4.1	3.2	2.9	3.0	3.7	4.7	6.2	7.8	8.2

2-10 Moonie Downhole Produced Groundwater Quality

The following Table 2-5 below, “Moonie well head water quality”, illustrates the general quality of the produced water from the oil reservoir. The Moonie Water Quality is within the EA licenced conditions. The water quality is analysed by a NATA accredited laboratory on a quarterly basis since 2015.

Table 2-5 Average Moonie water quality readings

Item	Unit	Measurement
Faecal coliforms	Orgs/100ml	<2
Blue green algae	Cells/ml	<4
pH		7.9
Total dissolved solids TDS	mg/L	1760
Oil and Grease		8
Magnesium	mg/L	<1
Calcium		16
Sodium		649
SAR		22
Bicarbonate as CaCO3	mg/L	1250
Chloride		-
Sulphate		8
Nitrate		0.01
Aluminium		<0.1
Arsenic		<0.001
Beryllium		<0.001
Boron		0.8
Cadmium		<0.005
Chromium		<0.01
Cobalt		<0.01
Copper		<0.01
Fluoride		6.8
Lead		<0.001
Mercury		<0.01
Molybdenum		<0.01
Nickel		<0.01
Selenium		27
Potassium		<0.001
Uranium		<0.001
Vanadium		<0.01
Zinc		<0.01

2-11 PL 1 Plan of Operations (PoO)

Under S 287 an updated Plan of Operations is required by the submission of this amendment. An updated PoO has been submitted to DoR as required by S 289 of the EP Act in November 2020.

2-12 Financial Assurance and Estimated Rehabilitation Costs (ERC)

Any additional Estimated Rehabilitation Cost for this initial project will be calculated and submitted prior to the commencement of the project. The change will be minor if any. The Bridgeport Environmental Management Plan and its Contractors environmental policy will manage all its production, drilling operations and construction activities on this project in a pro-active manner to minimise any environmental impacts from the development.

Through its EMS, Bridgeport has developed and implemented a structured environmental program that involves:

- identification of environmental aspects,
- environmental risk assessment,
- implementation of environmental mitigation strategies and controls to avoid or minimise environmental impacts,
- environmental monitoring, reporting,
- routine inspections and auditing programs,
- complaint investigation and resolution processes,
- a system of progressive corrective action should an incident occur,
- community consultation and engagement, and
- a regular scheduled management review.

2-13 Consultation Process

If this amendment is approved as requiring minor local disclosure, Bridgeport undertakes to discuss the project with all local landholders during the public disclosure period and address any new issues as they arise through this process. The current issues are:

- Is there additional compensation and are changes to the existing CCA required?
- Will there be any impact to our local water boreholes?
- Will CO_2 come to the surface? And impact my crops or livestock?
- What will happen at the end of the project will the CO_2 be sealed in the ground, and can it escape?
- Will all surface infrastructures be removed, and can I farm over the top of the abandoned wells?

These issues are addressed in the environmental assessment Chapters 10 & 17 and a community consultation plan is discussed in Chapter 18. Bridgeport will implement a yearly update to local landholders for the life of the project.

2-14 Legislative context

The EP Act 1994 and the Petroleum and Gas (Production and Safety) Act 2004 provides the principle legislative frameworks for facilitating resource projects in Queensland, including the Moonie Oil Field CCUS project. The Project is not subject to any approvals under the Queensland Planning Act 2014.

Bridgeport requires an amendment to the existing EA under the EP Act to enable the development of the CO_2 Initial EOR Injection Project. Section (s.) 223 of the EP Act sets out the definitions of "major" and "minor" amendments of an EA. For the reasons set out in the following section, this amendment to the EA is a "minor" amendment. As an approved Petroleum Activity, the project does not attract extensive consultation processes (other than consulting directly with local landholders and advertising for 21 days in the nearby newspaper, disclosure to Native Title holders and Council on an ongoing basis.

Several key areas need to be determined within Government regulatory authorities:

- Whether a waste stream of CO2 is classified as a minimal impact element in a sequestration situation on this EOR project,
- Whether deep aquifer CO2 storage could be considered as a beneficial public amenity,
- If there is any increase in local borewater well levels could indeed be considered as beneficial to local Landholders and have a preferential approval pathway,
- An acknowledgement that the reduction in GHG emissions from the Intergen Milmerran Power Station or other source represents a net benefit to the community and offsets any perceived detrimental aspect,
- An understanding by the Queensland regulators that this project once approved is expected to qualify for Australian Carbon Credit Units (as will the Santos Moomba CCUS project) and as such will provide an offsetting pathway for carbon, beneficial to those emitters of CO2 in the state who choose to purchase them.

2-15 Research Undertaken

There has been significant research into the potential CO_2 sequestration into the Surat Basin and in particular, the Moonie Oil Field, conducted by the University of Queensland (the Surat Deep Aquifer Appraisal Project (UQ-SDAAP)).

2-16 Reservoir Overview

The Moonie Oil Field has two significant oil-bearing formations, the lower Evergreen Formation overlying the lower Precipice Sandstone. The basal Evergreen Formation, known as the "56-sand" is equivalent to a sand within the UQ-SDAAP Transition Zone which has limited production history and has remaining primary oil recovery but from less permeable rock. The Precipice Sandstone "58-sand" is equivalent to the UQ-SDAAP, "Blocky Sandstone" reservoir and is the main producing oil reservoir which is well into late life depletion with water encroachment.

The Reservoir Statistics (at a glance) Table 2-6, is listed overpage.

Table 2-6, Moonie Oil Reservoir Statistics "at a glance".

Moonie Oil Reservoir Statistics, "at a Glance".					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Reservoir Stats					
Original Precipice oily water leg reservoir pressure (1,515m)	17,450	2,530			
Current Precipice oily water leg reservoir pressure (1,515m)	16,550	2,400			
Formation Slip Pressure					
Slip Pressure (P90=53,150kpa, mean 57,250 kPa)	51,700	7,498			
Formation Seals					
Seal thickness					20-100
Reservoir Fracture Seal Pressure	52,170	7,565			
Permeability - ultimate seal core plugs			0.003 - 0.086 av 0.037		
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809			
Bottom Hole Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712			
Permeability					
Bulk Permeability Precipice main water leg Horizontal, mean			580		
Precipice main water leg Horizontal, mean			127		
Ultimate Seal			0.003 - 0.086 av 0.037		
Pore Throat measurements					

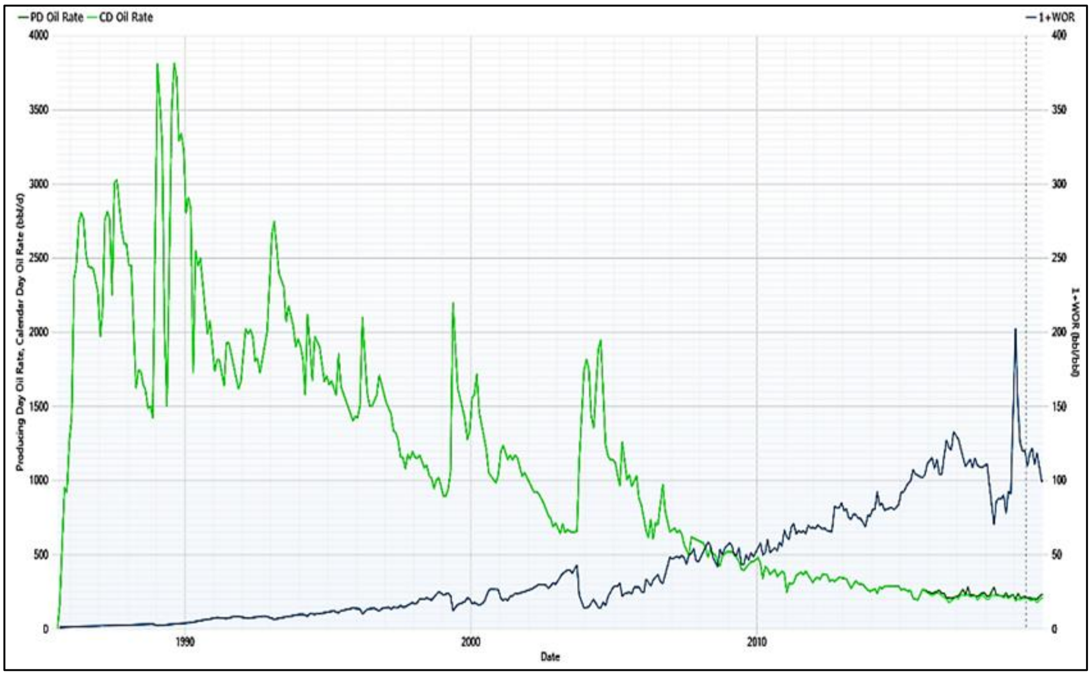
Moonie Oil Reservoir Statistics, "at a Glance".					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Precipice M38					0.01 - 100 µm
Porosity					
Evergreen				13	
Precipice (average Sandstone)				16.8	
Injection Statistics					
Gravity Head of the injecting fluid ($scCO_2$) - density of $480kg/m^3$	7,172	1,040			
Friction Loss of injecting	689	100			
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809			
Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712			
Miscibility * depends on temperature $scCO_2$ pressure range	11,380	1,605			
Estimated Injection pressure range, depends on temperature, mass, density, yield pressures.	11,380 to 39,388 Final depends on additional factors	1,605 to 5,712* Final depends on additional factors			

2-17 Oil Production History of the Moonie Oil Field and its status

The Moonie Field lies within the Surat Basin in southeast Queensland and oil was discovered by Union Oil in late 1961. It was the first commercial oil extraction development project in Australia and oil production began at Moonie in 1964 with the highest oil production rate of ~9000 STB/day (stock tank barrel/day) achieved in 1966 (O'Sullivan et al. 1991). Figure 2-6 below, illustrates the historical decline in the volume of oil production and the increase in water production. In recent times the trend has continued with declining oil production and increasing water production. Oil production commenced declining in 1991 and the field is currently producing oil at rate of about ~130 STB/day at an average of 95% water cut from most of the wells.

Implementation of tertiary recovery by way of the Enhanced Oil Recovery process (petroleum activity) will maximise the extraction of this resource for the State of Queensland.

Figure 2-6 Moonie Oil Field Production versus water production overtime



2-18 The reasons why the Moonie Oil Field is the best choice for EOR and CCS in the Surat Basin

The Moonie Oil Field has been selected as the best most suited location in the Surat Basin for a EOR and CCUS-CO_2 sequestration Project.

Several recent studies of Queensland's CCUS - CO_2 geological storage prospectivity and formations have been undertaken at the University of Queensland (UQ-SDAAP) and the results of these studies and research is noted throughout this document.

Within the Surat Basin Bradshaw[2] et al, 2011 ranked the results of the most prospective CO_2 acceptable formation candidates with the Precipice Formation selected as the most prospective. The

[2] *An assessment of Queensland's CO_2 geological storage prospectivity – the Queensland CO_2 Geological Storage Atlas, Energy Procedia 4 (2011) 4583-4590 ((GHGT-10))*

parameters considered by Bradshaw et al. 2011, are illustrated in the following list. The list illustrates the choice of the Precipice Formation in the Surat Basin, as a highly prospective location due to several factors listed, below:

- Existing effective seals (barriers) within the anticline formation, (i.e., upper, lower and horizontally),
- The anticline formation forms an effective trap for oil, gas and CO_2,
- Average net thickness of the formation is sufficient to hold 60MM tonnes of CO_2,
- Average Porosity of Precipice sandstone >16.8%3
- The effective type of the reservoir seal rock unit overlying the Basal (Evergreen Formation) is impermeable marine lacustrine shale and siltstone,
- The seal thickness varies between 50-100 m,
- The extensive storage area available in the Surat (39,491 km2), of which Moonie is a small part (4 X 16 km^2),
- The low permeability of the seal,
- The base seal depth is adequate, and
- The relative low number of faults in and through the seal due to the large transition zones on either side of the seals.

From a practical operations perspective the Moonie Oil Field is a good choice for a EOR – CCS - CO_2 sequestration project since existing extensive well and surface infrastructure exists and as a brownfield site it requires little further surface environmental disturbance (if any).

Further, the CO_2 sequestration will over time replace the volume of oil and gas already extracted and return the reservoir to its original reservoir pressure.

There is an economic synergy to be developed between sequestering large volumes of CO_2 and being able to finance the sequestration through increased oil production ahead of the advent of a price on carbon and / or the issue of Australian Carbon Capture Credits.

Bradshaw et al. 2011, further analysed the best choice field against the overall assessment parameters and concluded the Precipice sandstone provides consistently acceptable attributes across all the reservoir parameters.

2-19 The National Significance of the Initial CO_2 EOR Project

This initial CO_2 injection project (the subject of this minor amendment) is proposed to validate the proposed reservoir model and injection performance and comprises the pumping of up to 120,000 tonnes of CO_2 per annum into one existing injection well (Moonie 27) for eight years injecting 960,000 tonnes, sequestering 768,000 tonnes of CO_2. The expected enhanced oil recovery (EOR) will be seen initially in the production from the five to six surrounding production wells. The initial EOR project is to be implemented to confirm the efficiency of the carbon capture, utilization and storage (CCUS) technology at Moonie.

On a national basis, for each 1 million tonnes of CO_2 sequestered annually, which is planned when a larger industrial volume of CO_2 can be sourced, the full field EOR project will have met more than 12% of the current total 2020 National annual CO_2 reduction target. This is significant as it assists the Nation to meets its Paris agreement commitments. The National target is a reduction of 8% p.a. committed to by the Australian Government under the Paris Convention. For this initial injection project, the impact on the reduction target will be a contribution to this target.

[3] *An assessment of Queensland's CO_2 geological storage prospectivity – the Queensland CO_2 Geological Storage Atlas, Energy Procedia 4 (2011) 4583-4590 ((GHGT-10))*

For the initial CO_2 injection project, CO_2 will be delivered to the Moonie site via truck (like existing CO_2 transfer in the Food Industry). For the full field EOR project, the delivery of CO_2 will be via a dedicated high-pressure transmission pipeline (which will be subject to a separate high-pressure transmission pipeline PPL application and a further amendment application).

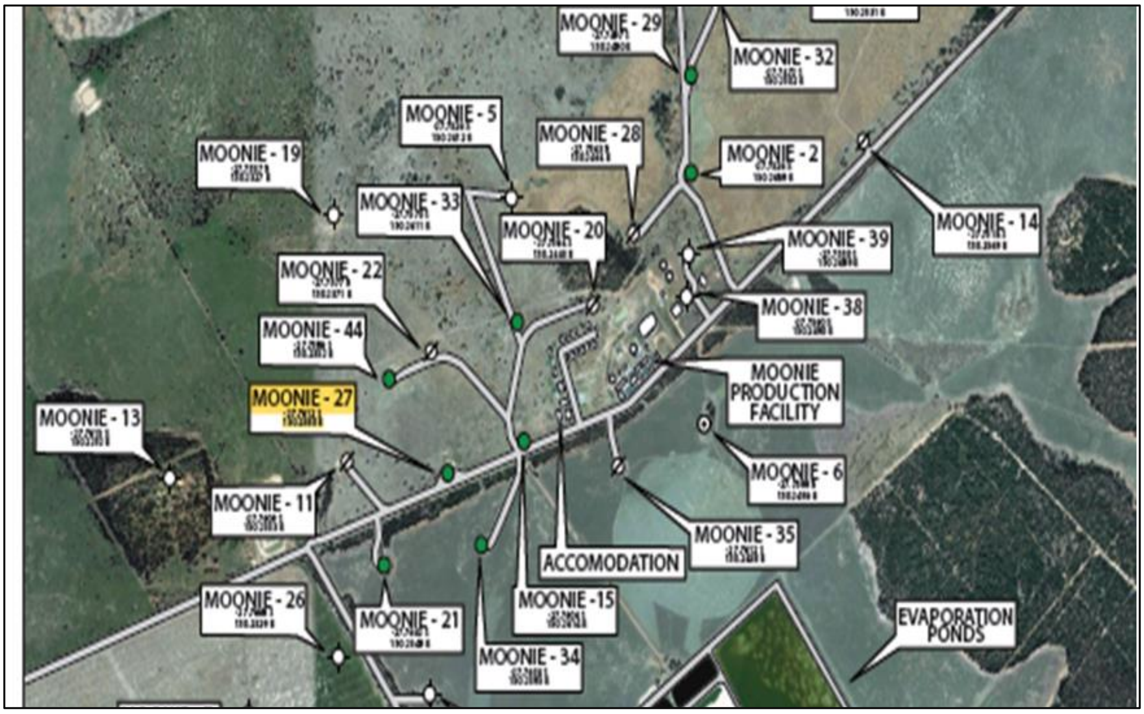
2-20 The Location of Production/Monitoring Wells

The initial CO2 injection project surface project area will cover an area of close to 2 hectares encompassing the location of the existing Moonie 27 (M27) see Figure 2-7 below. This area has been previously disturbed by agriculture and normal approved petroleum operations. This area occurs within the existing outer 5 monitoring wells and covers a surface area of 40 hectares. The monitoring wells are shaded green in Figure 2-7 below. The closest well is 285m from Moonie 27, the furthest is 569m with the average distance from Moonie 27 to a monitoring well is 450m. The production wells are illustrated in Figure 2-7 and are identified as:

- Moonie 21,
- Moonie 34,
- Moonie 15,
- Moonie 33,
- Moonie 44, and
- Moonie 22 and 11 may be brought back online during the project.

Within the 2 hectares, 0.5 hectare will be set aside as a CO_2 receival station. Figure 2-7 illustrates the location of the 5 production /monitoring wells.

Figure 2-7 The location of producing/monitoring wells at Moonie (green highlight)



Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 3: Initial CO_2 Injection Plan

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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3.1 Executive Summary

This chapter details the initial injection project plan to be implemented by Bridgeport Energy.

The project planning is ongoing however the on-ground works are scheduled to commence February 2023 subject to FID and approvals. The EOR injection will commence in late 2023 continue for a period of 8 years from successful commissioning, with the earliest end point for the project being Q1 2032, with an expectation to have sourced more material volumes of industrial CO_2 by that time and applications to progress for full field injection before 2031. If the project does not transfer to full carbon sequestration under the GHG Act and Regulations, the project will continue to produce oil until the field reaches its economic limit circa 2050 and then enter into the full rehabilitation phase at that time if the existing wells are not used for a later full sequestration project. The continuance of the project is subject to project curtailment which could be temporary or permanent at any time through standard risks such as economics, loss of supply of CO_2, downhole factors such as detailed in the contingency section 3.20, or a major oil price drop as seen in 2020 (see section 3:20).

The initial EOR project plan is to inject up to 120,000 tonnes p.a. of liquid phase CO_2 into the depleted Moonie Oil Field (PL1), for a period of eight years. Moonie well M27 is centrally located in the centre of the Moonie Field. The refined CO_2 delivered from the CTSCo owned post combustion capture plant located at the Millmerran Power Station (or from other sources) will be transported by truck to the receiving cryogenic storage tanks (-20C and 300psi) to be located on the well pad alongside M27. The liquid CO_2 will, if necessary for injection purposes, be directed via a thermal heat exchanger unit where the specific requirements for injection temperature tuned to the effective CO_2 conditions needed downhole, will be managed before injection downhole.

The combination of controlling the physical pressure and temperature will maintain the CO_2 in a super-critical state at the reservoir, enabling the oil to increase its miscibility and displace oil and water towards the five surrounding production wells. The ongoing pumping at the production wells will deliver the fluid component to the surface where oil and water will be extracted. In the initial stage’s eighty percent or more of the CO_2 will be trapped in the formation, while up to twenty percent may be discharged at the surface production facility separators. However, over the life of the project, CO_2 emissions will be carefully measured at the facility separator and if necessary, will be captured and redirected to the surface CO_2 tankage and thence into the M27 injection well. As the EOR process becomes uneconomic and/or as large-scale volumes of CO_2 can be sourced then application to move the site to full CO_2 sequestration and storage will be initiated under the GHG Act and Regulations.

The following phases will apply over the entire life cycle for the Initial CO_2 Injection Project,

- Planning (now to Dec 2022),
    - Project scope, preplanning, finalisation of the basis of design and issue of tender packages for equipment
    - Detailed site engineering for downhole and surface equipment,
    - Injection well and select production well integrity assessment,
- Construction, (July 2022 – 2023),
    - Installation of surface tankage and equipment, commissioning,
- Commencement of Injection Operations (Jan 2024)
    - Operations and monitoring,
- Shift of the Activity to Full Sequestration (prior to Dec 2031 when volume is available)
    - As oil production declines, application to shift the site to full field CCUS at 1MM tonnes PA
    - Up to four additional injection centres in the field and 24 production wells
    - Economic assessment will determine the onset of the final phase “abandonment and decommissioning”.
- Abandonment and Decommissioning (2050)
    - Decommissioning, rehabilitation plugging and abandonment, and
    - Final handover to the State.

If the project becomes non-economic for some reason earlier than scheduled and the wells are no longer to be utilised under the existing PL 1(1) and associated EA, the close out program as detailed in this chapter 3. 18 and detailed in Chapter 4 would be brought forward and implemented.

In each phase, the requirements, checks, and balances contained within the Petroleum and Gas Act and Regulations, the EPAct & Regulations, API Standards, the Industry Code of Practice for Well Construction, Australian standards and guidelines and the Environmental Authority will be applied. As the Moonie Oil Field is the oldest field in Australia, there is great knowledge with operating the oil field and facilitating the monitoring aspects and controls for the project.

Based on the final Basis of Design and the detailed engineering process this may slightly change the specifications discussed below.

3.2 Introduction

The Initial CO_2 injection plan is illustrated in Figure 3.3, below. The CO_2 being captured from the Millmerran Power Station (or similar) and transported by truck to the Moonie Oil Field, will be temporarily stored and then thermally adjusted before being pumped into the Precipice oil and water reservoir via the injection well M27. During the initial project 80% of the CO_2 is sequestered as the miscible flood front travels with the miscible oil water fraction and the remaining 20% CO_2 to the producing / monitoring (PM) wells where the oil and produced water is pumped to the surface. The miscible flood front will move in the sandstone layers of the Precipice depending on relative permeabilities (faster in higher, slower in lower).

Figure 3-1 below, illustrates a 4-inch core sample from an oil field with conventional extraction similar to M27 that had reached the end of its economic life again similar to M27 with 99% watercut production. You can see evidence of the 35% immobile oil within the sandstone. Figure 3-2 illustrates a core sample from the same well post CO_2 flood. Here the CO_2 replaced oil reducing the oil level from 35% to 20% with the water remaining in place.

Figure3-1 a 4-inch sandstone core sample with 35% oil saturation and water

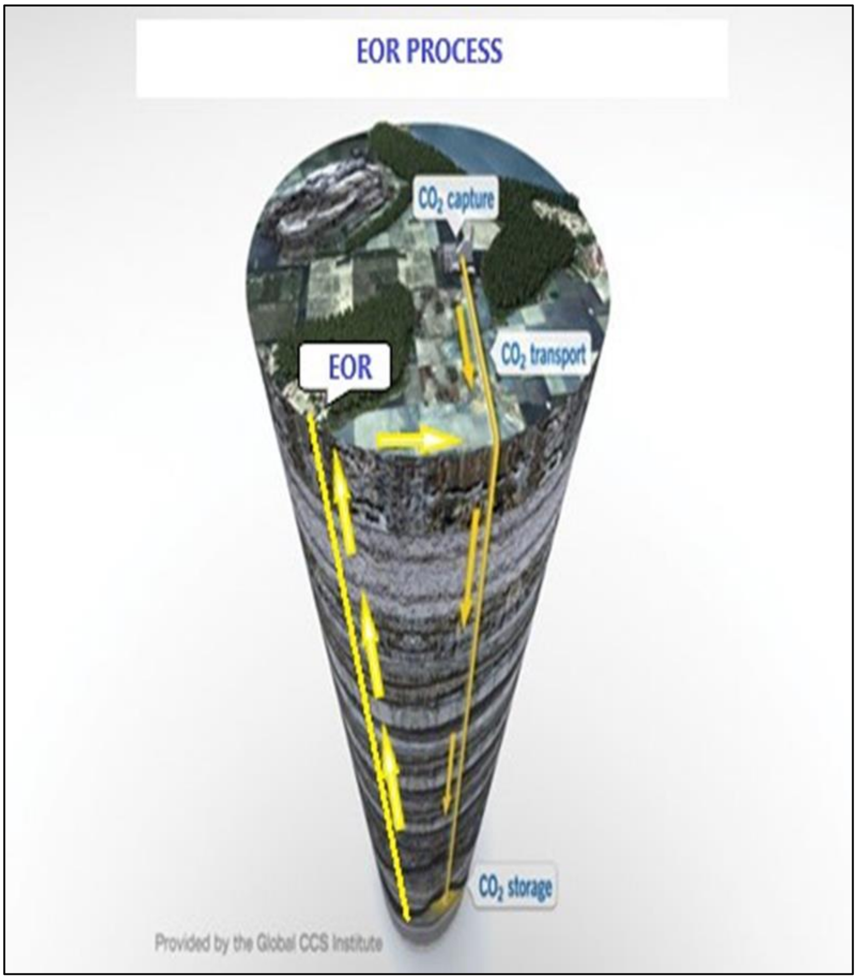
Figure 3-2, a 4-inch sandstone cores sample post CO2 sweep with 20% oil and remainder CO_2 and water

On reaching the surface the water, oil and gas are directed to a separator where the gases and water are separated from the oil. Subject to the efficiency of the CO_2 sweep in the reservoir up to 20% of the injected CO_2 and methane from the separator go to the dual fuel generators and are released through the combustion process in that ICE engine in the same way as the current producing wells.

In the event that there is an emergency diversion of the separated gases, the facility is currently designed to release gases via a flare tower designed to API specifications for controlled venting. Where possible all the CO_2 will be captured and re-injected subject to economic assessment.

Figure 3-3, A 3D diagram of the Initial CO_2 Injection Project is illustrated overpage,

Figure 3-3 A 3D diagram of the Initial CO2 Injection Project



The following text details the Regulatory Requirements for pre-planning, construction, operation, plugging and abandonment, and de-commissioning of the Initial CO_2 Injection Project.

The Moonie CCUS project is e located on a “brownfield” site which is environmentally and culturally approved for existing oil production activities. There are no additional Landholder requirements beyond updating the existing CCAs (Landholder Conduct and Compensation Agreements).

3.3 Key Project Parameters - Pressure of the CO_2 stream to be injected

The stream of liquid CO_2 will be thermally adjusted and at a pressure designed to penetrate into the permeable formation at the injection zone. From Chapter 8 Predictive Reservoir Models and Petrophysics, this pressure will be above the existing reservoir pressure of 16,550 kPag (2,400 psi) and significantly below the formation fracture pressure of 52,170 KPag (>7,566 psi). A maximum upper injection pressure will be limited to 90% below the fracture pressure, being 46,953 kPa (6,809 psi). Further an adjustment of another reduction of 14.5% for thermal considerations sees the maximum injection pressure set at 39,388 kPag (thermally adjusted), or ≤ 5,712si.

3.4 Project scope, preplanning, and the basis of design (BOD)

The entire project injection area and the existing Moonie Oil Field Infrastructure will be reviewed during the detailed design phase commencing Q3 2021 and current Basis of Design modified as necessary. The detailed design phase will firm up the project design and its specifications in line with finalised project requirements, legislative requirements, industry standards and well construction Codes of Practice.

3.5 WIMS Well Integrity Management System

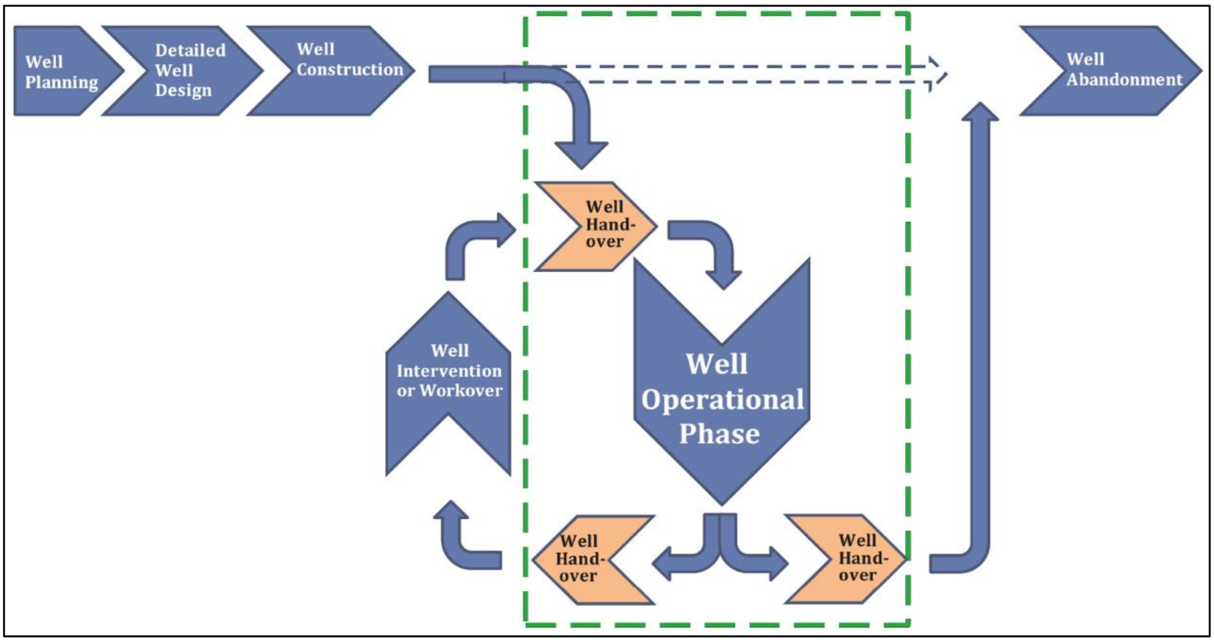
In Queensland, the Petroleum and Gas Industry Safety is regulated under the Petroleum and Gas (Production and Safety) Act 2004 (P&G Act) with the main subordinate legislation relating to safety being the Petroleum and Gas (Safety) Regulation 2018 (P&G Safety Regulation). Bridgeport Energy applies these safety requirements for all its operations including the existing Moonie oil field operations and will continue to do so for each stage of this project.

It is a requirement to comply with the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Version 2, 16 December 2019 (Code of Practice).

The Code of Practice was compiled by the Petroleum and Gas Inspectorate with significant input from Queensland petroleum lease operators and stakeholders.

Bridgeport Energy manages well integrity though the well life cycle by applying its Well Integrity Management System (WIMS) as required by Code of Practice. This process is illustrated in Figure 3-4, below.

Figure 3-4 A diagram of the WIMS management process



3.6 Planning & Design Phase

3.6.1 Well & surface equipment design

The design of the well heads (injecting and producing) and related subsurface equipment in the Moonie field was carried out in accordance with the following standards and codes. Additional work and recompletion of existing wells and wellheads will follow these same codes especially international standards such as API around the selection of steel material and elastomers for super critical CO_2:

- Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Section 3.2 Well design and barriers, Section 3.3 Casing and tubing and Section 3.8 Wellheads,
- Design process to identify maximum loads and selection of high strength material,
- Completion tubing and packer installed in well to isolate the production casing from high injection pressures,
- All completion equipment must comply with the relevant completion equipment API/ISO standards,
- API Specification 5B, Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing and Line Pipe Threads,

- API Specification 5CT/ISO 11960, Specification for Casing and Tubing,
- API Specification 6A/ISO 10432, Specification for Wellhead and Christmas Tree Equipment,
- Design process to identify maximum loads and selection of Corrosion Resistant Alloys (CRA),
- Elastomers which are tolerant to CO2 in its operating phase envelope,
- Tubing stress analysis performed with the aid of an industry recognised software to select tubing strength properties,
- BEL Management of Change Procedure,
- Completion design process,
- May include downhole safety valve (DHSV) in completion string depending on initial engineering design.

3.6.2 The Location of Monitoring Wells

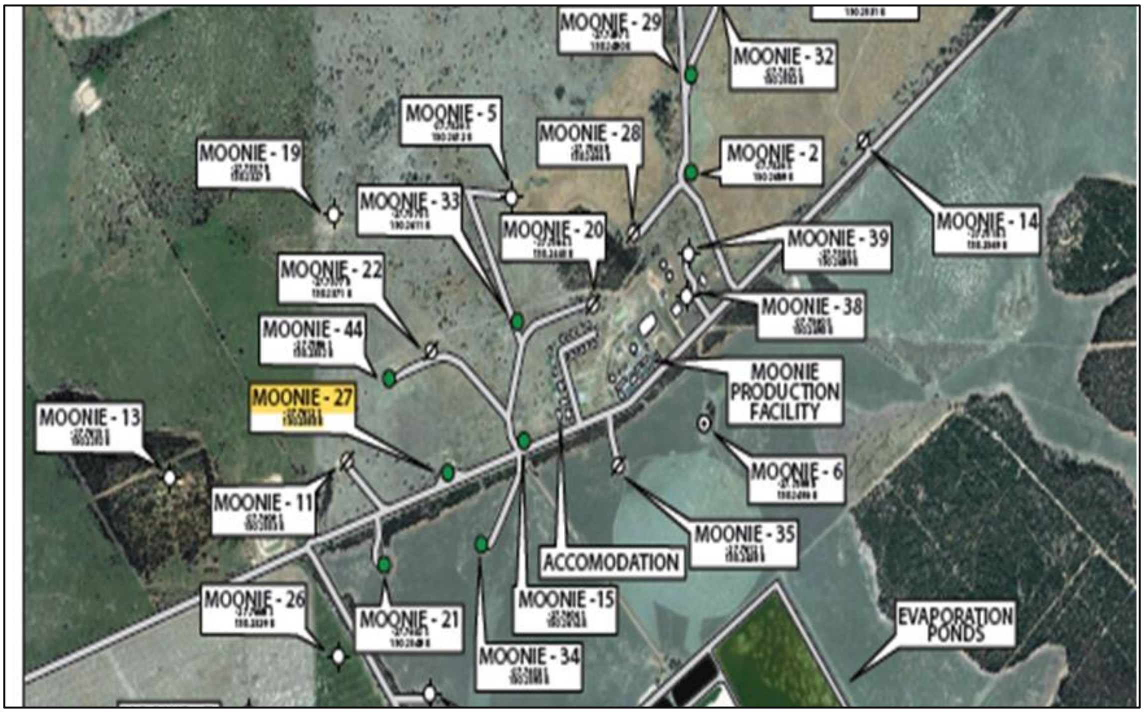
The Initial CO2 injection Project will cover a surface area of close to 2 hectares encompassing the location of the existing Moonie 27 (M27) and well pad. This area has been previously disturbed by agriculture and previously approved petroleum operations. The nearest Production / Monitoring wells (PM wells) are shaded green in Figure 3-3 below. The closest well is 285m from Moonie 27, the furthest is 569m with the average distance from Moonie 27 to a PM well, being 450m. Subject to final assessment the potential PM wells are illustrated in Figure 3-5 and are identified as:

- Moonie 21,
- Moonie 34,
- Moonie 15,
- Moonie 33,
- Moonie 44

Moonie 22 and 11 may be brought back online during the initial injection phase as additional PM wells. Of the project area, approximately 0.5 hectare will be set aside as a CO_2 receival station with cryogenic storage tanks.

When considering the physical size of the sub-surface injection project, the area sub-surface between the 5 production wells represents a total sub-surface footprint of 40 hectares. Figure 3-5 overpage illustrates the location and spacing between the PM wells.

Figure 3-5, The location and spacing between PM wells



3.6.3 Fit for Purpose validation process

The DES concerns related to the integrity of the existing wells at Moonie will be addressed during the validation and design phase. The validation process is detailed below:

3.6.3.1 Current Wellheads

The current wellheads of the PM wells and the injection well will be validated as fit for purpose by,

- Assessing condition based upon procedures from the Original Equipment Manufacturer and API standards.
- API Specification 6A/ISO 10432, Specification for Wellhead and Christmas Tree Equipment.

3.6.3.2 The Injection Well – cement sheath

The existing injection well will be validated as fit for purpose by validating the existing borehole cement sheath condition,

- Run electric wireline log to evaluate position and condition of cement sheath.
- Assessed by industry specialists.
- API Technical Report 10TR1 Cement Sheath Evaluation and or Society of Petrophysicists and Well Log Analysis (SPWLA).

3.6.3.3 The Injection Well – production casing and tubing

The existing injection well will be validated as fit for purpose by validating the existing condition of the production casing,

- Run electric wireline log to evaluate condition of production casing.
- Assessed by industry specialists.
- Confirm production casing strength and integrity meets well injection design requirements.
- New corrosion resistant alloy (CRA) tubing and an isolating packer will be run in the well.

3.6.3.4 Production and Monitoring wells - tubing

At the production and monitoring (PM) wells the tubing will not be upgraded until CO_2 is detected at the wellhead. As CO_2 breakthrough at these wells may occur between 6 months and 2 years after injection starts, to mitigate the possibility of CO_2 materially affecting the existing production casing, monitoring of the wellhead gas content will be undertaken quarterly by sampling and lab analysis. As CO_2 contents begin to rise above current base field CO_2 levels of 5%, the wells will be monitored more closely and as content approaches 15% the wells will be shut in and workovers planned. A key outcome of the proposed injection program is to determine the actual performance of CO_2 in the oil reservoir. If the CO_2 flood front moves in a stable and uniform manner, it may take as much as two years for the flood front to arrive. However, it is also possible that the CO_2 flood front moves more quickly in layers of higher permeability and could arrive at the producing wells in a shorter period.

3.6.3.5 Production and Monitoring Wells – Casing

Once CO_2 has arrived at a PM well and the partial pressure calculations indicate an increasing corrosion rate, that PM will be shut in, then the tubing will be retrieved, and production casing integrity confirmed as per the injection well. Following that analysis, CRA packer and tubing completions may be run subject to corrosion rate analyses indicating a need for replacement. This process will be repeated at each PM well as the CO_2 arrives at the well and within 4-6 months of arrival.

- Shut in well, undertake workover to remove tubing then
- Run electric wireline log to evaluate position and condition of cement sheath.
- Assessed by industry specialists.
- API Technical Report 10TR1 Cement Sheath Evaluation and or Society of Petrophysicists and Well Log Analysis (SPWLA).

After analysis of corrosion rates in accordance with API standards, an isolation packer and tubing made from CRA materials may be run into the wells and production resumed.

3.7 Construction Activities

The construction activities at the Moonie Oil Field will include;

- minor upgrade of the existing road access from the Moonie process facility to the EOR project area to accommodate the trucked CO_2 delivery and egress loop to the M27 injection site,
- retrieval of the existing tubulars in the M27 well and validation of the production casing and cement for future use
- the replacement of the injection well tubulars and installation of wellhead to corrosion resistant alloy (CRA) material at M27,
- the construction and installation of a skid mounted cryogenic CO_2 storage facility and liquid CO_2 unloading facility,
- the establishment of contained bunding for liquid CO_2 will be assessed,
- the conversion of existing production well surface infrastructure to be fit for purpose,
- the dedication of gathering lines of CRA or composite materials for the return surface pipes to the main processing facility,
- installation of a CO_2 pump with heat exchanger and associated piping,
- review of existing sediment and erosion controls to ensure compliance with EA,
- the provision of safety equipment and PPE stations,
- the installation of all ancillary control, electrical communications, wellhead PCE controls and monitoring infrastructure to the main production facility,
- based on the increasing concentration of CO_2 in the producing fluid, the well tubulars in the adjoining PM wells could be replaced with CRA or such other material sufficient to meet the API standard and corrosion rate determinations for the well service life, and
- Any other workover of wells as necessary to maintain well integrity as stipulated by WIMS and Codes of Practices.

3-8 Estimated disturbance area at the well head

The proposed area has previously been disturbed by agricultural and petroleum industry activities. No new environmental disturbance is anticipated. In close proximity to the existing drilling pad at M27, the additional estimated area for the heavy vehicle turnaround and laydown surface area is 0.5 hectare with an additional area for access of 0.5 hectare, making 1-hectare pad in total. No other disturbance is expected, although the detailed design process may make minor changes to this estimate. The areas are detailed in Table 3-1 below.

Table 3-1 Estimate of the Proposed Disturbance Area (Hectares) at M27

Infrastructure	Estimated proposed short-term disturbance (ha)
Additional turnaround area	0.5
Laydown area (including new facilities)	0.5
Existing pad area at Moonie 27	1
Total disturbance	2

3.9 Long term surface disturbance

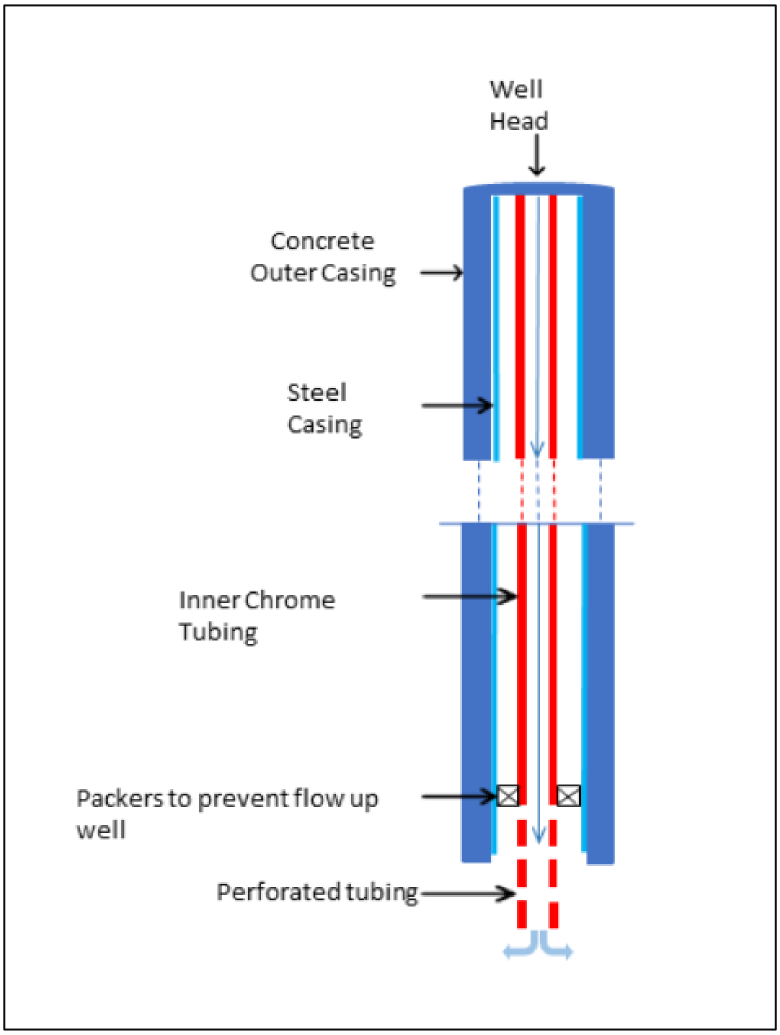
There will be no further disturbance in the area above that shown at 3.9. Any longer-term surface disturbance will occur when the initial CO_2 – EOR project is proven successful, and a long-term source of CO_2 can be found. This would be the subject of a further amendment to inject up to c1MM tonnes per annum when a CO_2 supply quantity of this magnitude can be found.

3.10 Upgrading wells and existing infrastructure for CO_2 Injection

Moonie 27 will be recompleted as a CO_2 injection well. A corrosion resistant alloy (CRA) tubing and production casing isolation packer will be installed downhole with wellhead infrastructure and valving of similar metallurgy installed on surface.

The five to six surrounding PM wells will also be upgraded progressively as CO_2 arrives at the well by inserting similar tubing and downhole isolation packer to ensure the production casing is isolated from the produced fluids. Packers will be placed immediately above the downhole perforations through which the produced reservoir fluids will enter. The packers and completion tubing effectively isolate the existing production casing from any contact with the produced fluids. The area between the production casing and the completion tubing is referred to as the production annulus. Refer to Figure 3-6 below, for a cross-section of the injection wells. Surface gathering flowlines will be replaced with or directed through existing lines with materials suitable for transporting the produced and injection fluids.

Figure 3-6 Illustration of the cross-section of the injection well



The rig operations for the installation of completion tubing and packers will be managed in accordance with Department of Resources Queensland regulations by the application of the,

- Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Section 3.9 Well Control, Section 3.14 Workover, and intervention,
- BEL Drilling Manual,
- Rig Contractor's management systems,
- API and industry standards for the selection of CRA products and tubular handling procedures and competencies.

3.11 Injection Pressure, and Temperature monitoring

The liquid CO_2 stream supply will be at -20^{0}C and 330 psi, detailed design will determine the injection temperature. At a pressure of 20 MPag and 10°C, the density of the liquid phase is 949 kg/m^3. The intent is to maintain the CO_2 in liquid phase throughout the injection process and into the reservoir. In the reservoir the CO_2 will be in the supercritical phase which it reaches at 1,085 psi and 30^{0}C as in the diagram below. Within the reservoir, pressures and temperatures above the critical point ensure the CO_2 remains in supercritical phase.

Pressures need to be maintained in storage and in the tubing to keep the CO_2 in liquid phase. In the reservoir the fluid moves to supercritical and then after exiting the reservoir into liquid and eventually gaseous phase in the tubing. Where possible in surface piping the CO_2 will be kept at temperature and pressure to keep the CO_2 in liquid phase so as to prevent two phase and potential ice formation. Contingency for methanol injection at the PM wellheads and in surface gathering lines will be installed as contingency to eliminate ice formation.

The CO_2 Injection pump will have a governor set so it is unable to exceed maximum allowable operating pressure of the wellhead completion string and the formation, while delivering sufficient pressure and temperature to realize and maintain downhole CO_2 state.

A Pressure relief valve will be placed in the system, so it is unable to exceed maximum allowable operating pressure.

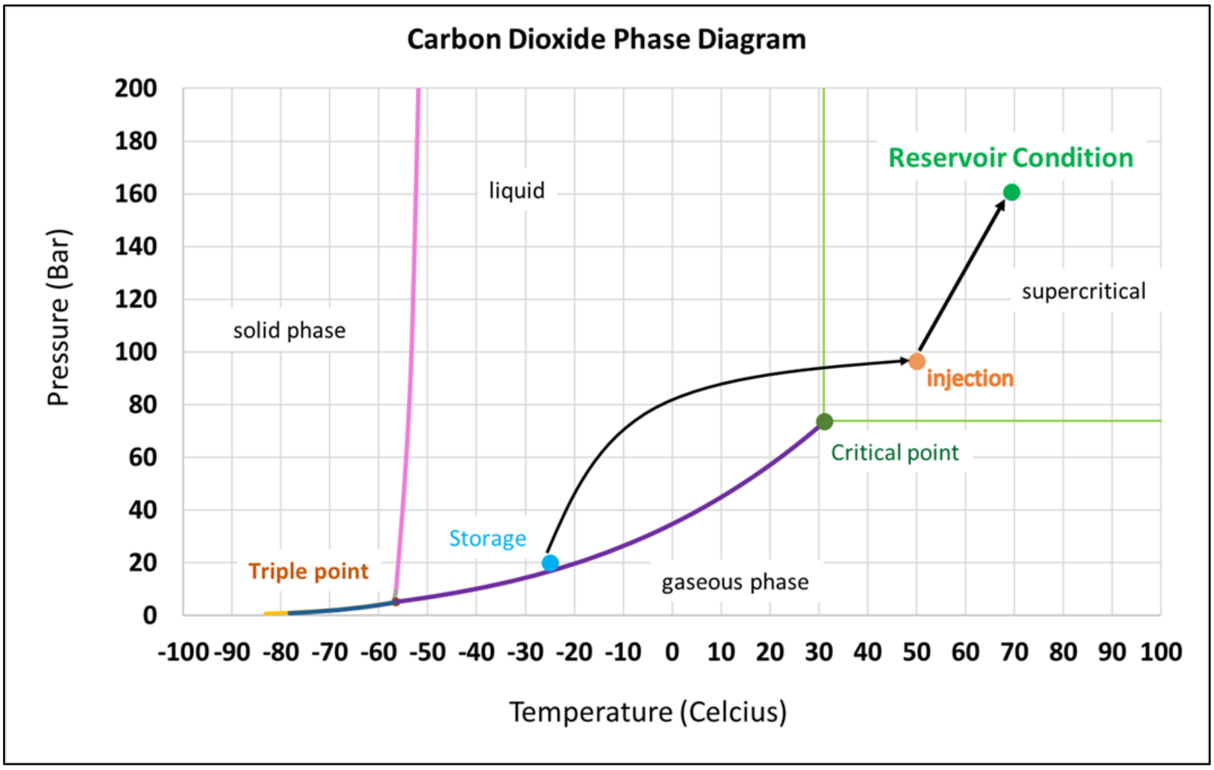
The Operations team will prepare and implement operations and maintenance procedures.

On the injection well a downhole pressure gauge will be installed to monitor and optimise injection parameters.

The monitoring points will be the injection well and the 5 surrounding PM wells, and CO_2 levels will be monitored at the surface through regular wellhead sampling and analysis at a qualified laboratory.

Figure 3-7 below, illustrates the Phase envelope for CO_2, with precise temperatures and pressures confirmed in the Process engineering phase of detailed design.

Figure 3-7 Phase Diagram for $scCO_2$ showing the critical point, approximate conditions at which Injection will take place



3.12 Commissioning

Each part of the project equipment will be tested under operating conditions including the CO_2 unloading, storage and injection facility, production, and monitoring facility to meet operational and project criteria. It will then go through a commissioning phase prior to turnover to operations. During the commissioning phase, each part of the unloading, storage, injection, and monitoring functions will undergo a trial under operational conditions.

3.13 Operations

The Operational phase includes,

- CO_2 unloading,
- CO_2 storage,
- CO_2 injection,
- Crude oil production & processing,
- Well and separator gas sampling and management (monitoring),
- Methane and CO_2 management at surface (downstream of the separator), and

- CO_2 monitoring and receival management.

The operating pressures are detailed in Table 3-2 below,

Table 3-2 Key Operating Pressure Reference Table

Item	kPa	psi
Gravity Head of the injecting fluid ($scCO_2$) - density of 480kg/m^3	7,172	1,040
Friction Loss of injecting	689	100
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809
Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712
Miscibility * depends on temperature $scCO_2$ pressure range	11,380 to 15,960	1,605 to 2,314
Estimated Injection pressure range, depends on temperature, mass, density	11,380 to <39,388	1,605 to <5,712

For all 7 principal wells involved in the initial EOR project, cement bond logs will be performed when they are worked over in order to validate the integrity of the cement sheath and production casing in key sections above the reservoir.

Wellhead pressure gauges will be used to monitor annulus pressures of the PM wells with data stored and analysed at regular intervals. This information will be stored and analysis with reporting to the regulator biannually or as frequently as specified.

Quarterly gas samples will be taken at PM wells or at the facility test separator when wells are individually tested, with gas analysis conducted to measure any CO_2 contained in the production stream, confirming that the producing GOR matches reservoir modelling expectations and to determine the absolute content of CO_2 returning at each well. This will help inform the decision as to the acceptable level of CO_2 above which the well will have to worked over and, production casing integrity checked, and tubulars and wellhead changed out.

A material balance of injected and recovered fluids, in line with good oil field practice, will confirm the total CO_2 sequestered, subsequently reported and be compared to reservoir model expectations.

3.14 Daily CO_2 operations

3.14.1 Delivery of CO_2

The liquid CO_2 will be received at Moonie at low temperature (below -20°C) and moderate pressure (330 psi) transported in special purpose ISO containers designed for CO_2 carriage and transported on standard B double trucks.

Within the Moonie 27 immediate area, a heavy vehicle receival facility comprising a turnaround bay and discharge station will be created using the existing dual carriage way road at the facility.

The Truck delivery hoses will be connected to a CO_2 storage tank sufficiently sized to service a daily injection rate of 150 tonnes/day, the tanks will maintain the CO_2 at a temperature and pressure of approximately -20ºC and 2,275 kPag sufficient to ensure it remains in the liquid phase. The pump size and piping capacity will be finalised in the design phase and will be fit for purpose.

3.14.2 Storage of CO_2

The storage tank will be purpose built to Australian Standards for cryogenic storage of liquid $CO_2$to ensure the CO_2 remains in a liquid phase. The storage tank discharge piping will be designed to maintain temperature and pressure. Detailed design will be conducted to determine if a heat exchanger is necessary prior to injecting the product.

3.14.3 Delivery Specification

The specification of the CO_2 to be delivered from CTSCo at the PCC plant at Millmerran into the ISO containers will be liquid CO_2 at -20C and 330psi (2,275 KPa) with the gas specifications shown in table 3-3 below.

Table 3-3 Delivered Gas Specifications

Constituent	CTSCo PCC Plant Warrantee Output Soec	CERI PCC Plant Actual Operating Data
Carbon dioxide	>98 vol%	>99.5%
Water	<150ppmV	<150 ppmV
N2/ Ar/ H2	< 2%	<0.5%
Other Hydrocarbons	< 0.1% v/v (1000 ppmV)	0
O_2	100 ppmv	~100- 400 ppmV
Carbon monoxide	200 ppmv	0
NOx (expressed as NO2)	33 ppmv	10~15 ppmV
SOx (expressed as SO2)	20 ppmv	2~5 ppmV
Particulate loading	10mg/m3	<5 mg/m3
Amines (MEA)	6 ppmV	~ 1ppmV
Ethyene Glycol	40 ppmV	0
Hydrogen Sulphide	15ppmv	0
Other externalities	Zero	0

3.14.4 Transfer of CO_2 to the Injection Skid

A cryogenic pump will transfer liquid CO_2 to the reservoir via the wellhead. This injection pump will pump at a pressure that exceeds the reservoir pressure but maintains the desired CO_2 pressure and doesn't exceed the maximum thermally adjusted injection pressure.

3.14.5 CO_2 Injection & Injection Skid

Liquid CO_2 will be transferred via a manifold to CO_2 pumps sufficient to pump into the formation via the well tubing into the reservoir. Both the CO_2 pump and any heat exchanger equipment will be powered by existing distributed electricity supply at the field.

3.14.6 Connecting Pipeline and related Infrastructure

An extensive pipeline network and related infrastructure network exists at Moonie. There will be minor additional disturbance (if any).

3.15 Production Operations

The objective is to achieve an injection volume of ~300 T/day of CO_2 (8-900 bpd) from >2,275 KPag at ambient temperature, while maintaining normal ongoing production activities separating oil from produced reservoir fluids (water and oil) from the existing production wells at the main production facility. The separated products comprising oil, water and gas will be directed as it currently is: oil, will be to oil storage tanks and then to market through existing dedicated infrastructure, water, will be to the evaporation ponds and gas, (including any CO_2) will be to the gas generators to burn and generate electricity. The continuous operation of the PM wells identified as part of the pilot EOR project are expected to be no different from others in the oil field. The ongoing processing of the reclaimed oil is already accommodated within the existing EA and is not part of this amendment. No additional fluid storage or produced water pondage is required.

Once CO_2 breakthrough occurs at the PM wells, twenty percent of the CO_2 injected volume is expected to be produced with the reservoir fluids which will separate with the existing methane gas at the surface separator unit and will form part of the fuel gas stream burned in the existing power generators. Bridgeport Energy will consider recycling the CO_2 gas from the production separator as levels approach 20% and, subject to commerciality of the outcome could install compression at the injection well for the gas stream to be reinjected into the injection well at M27. The composition and volume of the gas stream will be monitored and as with oil and water production rates and CO_2 injection rates, will be used to compare and as necessary modify reservoir simulations of events.

Full field CO_2-EOR development will result in larger volumes of CO_2 accompanying production. For this case the volume of produced CO_2 will make commercial sense and warrant installation of compression and dehydration facilities to recycle the produced CO_2 as part of the CO_2 injection stream. The processing and compression of the recycled CO_2 will form part of a separate and future EA amendment for the full field CO_2-EOR project when a sufficient quantity of CO_2 at 1MM tonnes per annum can be sourced.

Controls will be needed to control injection pressure and rate to control Bottom Hole Pressure (BHP) to below the seal formation fracture pressure. This will ensure inherently that no damage to the Precipice formation seals will occur.

As a minimum, the control and communication systems required consist of the following, housed in the existing production control room:

- Main switchboard,
- Control and safety shutdown system,
- Communication panel, including (CCTV) converters, and
- Uninterruptible power supply/ battery charger

3.16 Injection and Operations - Monitoring during operations

Regular monitoring of the casing annulus pressure which will be a closed volume will ensure a possible downhole leak is immediately identified. Should an anomaly be identified, the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Section 3.13, Well integrity, will be followed. The contingency procedures comprise shutting in the well and performing a remedial workover operation to re-establish the annulus integrity and seals.

A downhole temperature gauge will be installed on the completion to monitor injection parameters. The temperature and pressure of the injected CO_2 will be modified to provide optimum conditions downhole.

3.17 Decommissioning and Abandonment (P & A) of wells

Production wells will be abandoned as per requirements of the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Section 3.16, Well abandonment. This procedure includes a 6-month monitoring procedure after final well closure, prior to final Notice of abandonment. The final abandonment of the field irrespective of the time and duration of CO_2 is 2050 based on current oil production and reservoir modelling.

The following standards and procedures apply as of 2021. There is no doubt that these specifications will change in the next 25 years.:

- API Specification 10A/ISO 10426-1 Specification for Cements and Materials for Well Cementing,
- API Recommended Practice 10B-2/ISO 10426-2, Recommended Practice for Testing Well Cements,
- API Recommended Practice 10B-6/ISO 10426-6, Methods of determining the static gel strength of cement formulations,

Based upon final condition of the M27 injection well 5-½" production casing and cement an option to section mill the casing and cement to allow placement of an abandonment plug, with modern cement products, against the geological seal will be considered, or whatever best practices are available from 2045.

As of the date of this document, wells will be abandoned as per requirements of the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Section 3.16, Well abandonment dated 2019 with the Abandonment, Decommissioning and Rehabilitation Plan detailed in Chapter 4.

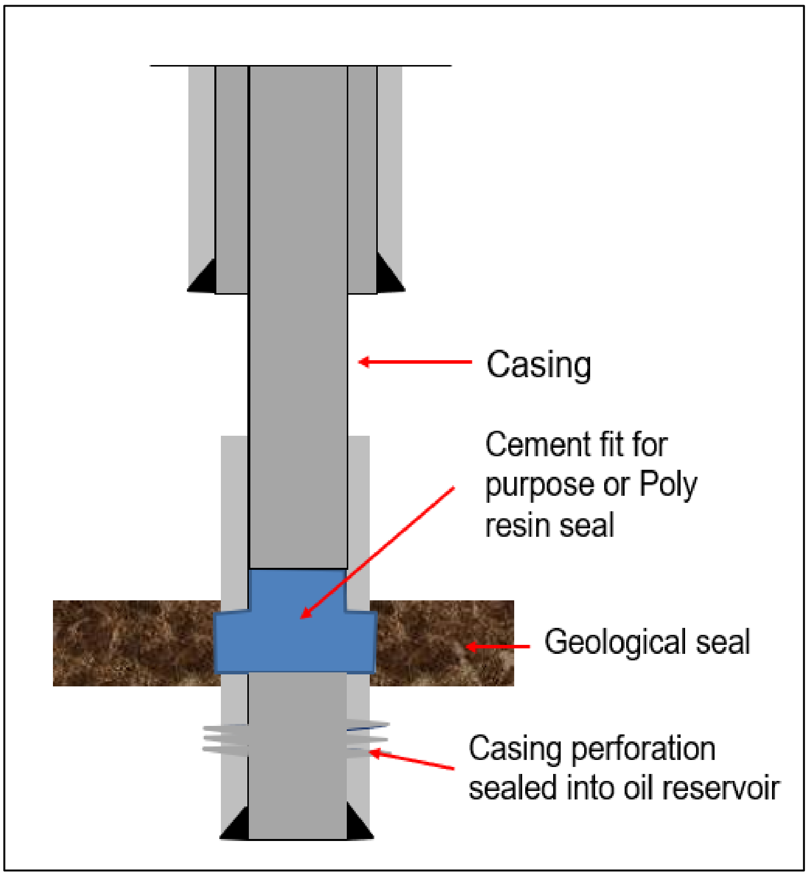
The final well abandonment procedure designed as of the date of this document is detailed in the next section. Note that final well abandonment procedures are expected to change and best engineering and oilfield practice will be followed in 2050 when abandonment is expected.

3.18 Final Well Abandonment Procedure

- Pull completion tubing & packer.
- Run electric logs to evaluate casing & cement.
- Set cement plug across perforations in reservoir.
- Mill out section of casing and cement to expose geological seal.
- Set cement plug across geological seal, and
- Set cement plugs in upper wellbore and in annulus as required by Code of Practice.

The following diagram Figure 3-8 illustrates the final milling and seal plug to be inserted when finally abandoning a well.

Figure 3-8 The final milling and seal plug inserted at final abandonment



3.19 Long term residual risk

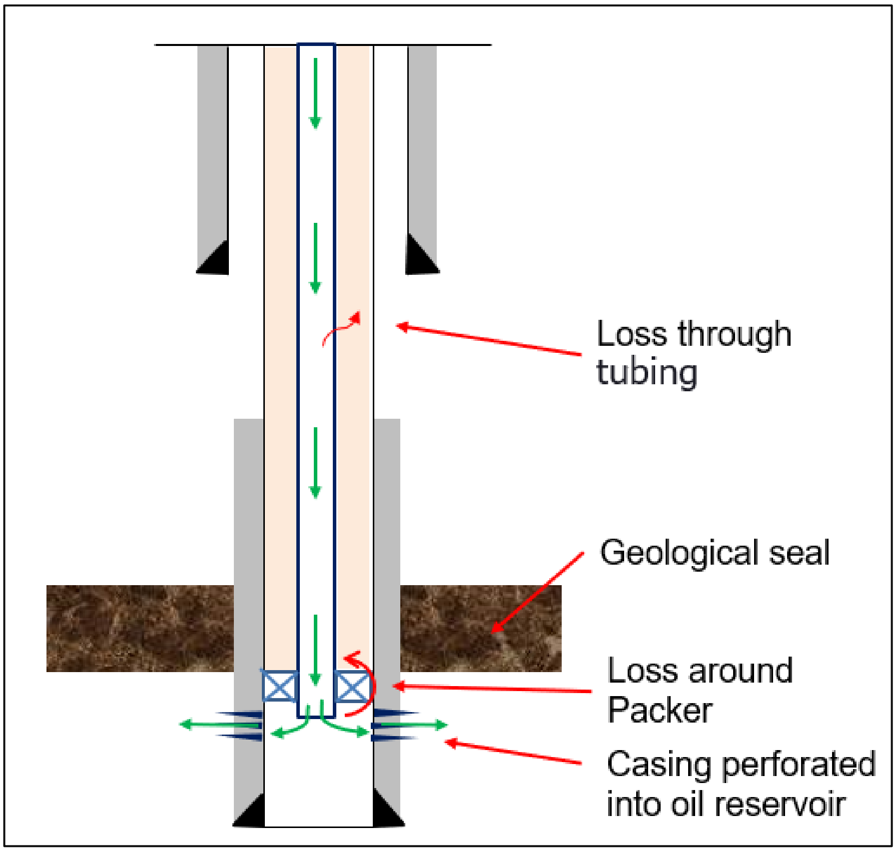
As with all other petroleum wells, the land access and residual risks post abandonment would be for future responsibility and management of the Queensland State when the tenement is released at the end of the permit (expected in 2050 as at the date of this document).

3.20 Contingency Plans

3.20.1 #1 & #2 - Contingency Plans

Bridgeport will apply their normal well integrity management processes and be ready with contingency plans for any issues. If there is a leak past the tubing packer into the production annulus area of the injection well then regular workover activities can be performed to re-instate the integrity. The following diagram figure 3.9, illustrates two contingencies, and the following text describes the contingency management plan applied in the field.

Figure 3-9 Contingency Plans for loss around casing or packer.



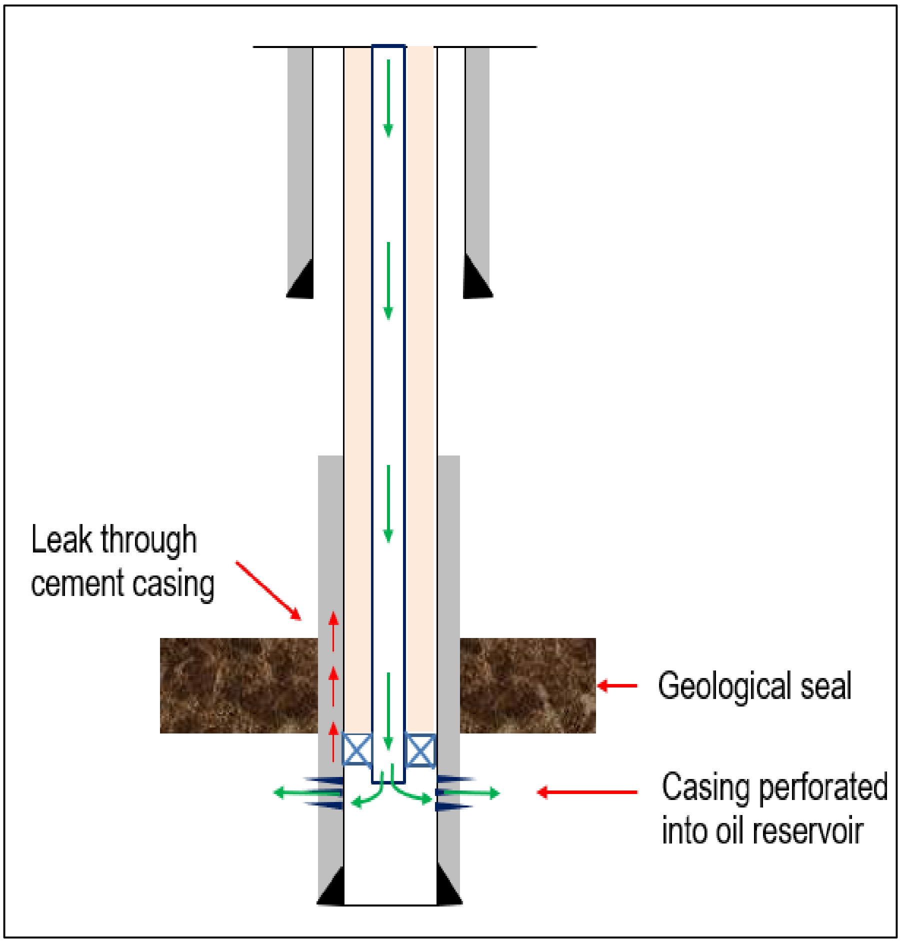
The contingency plan for a leaking packer or tubing is:

- Pull completion tubing & packer if there is a leak.
- Install new completion tubing and packer.

3.20.2 Contingency Plan #3, Leak through Cement Casing

The following diagram illustrates a leak path through the cement sheath around the production casing above the reservoir, (see Figure 3-10 below). The following shows the contingency procedure to remediate the issue.

Figure 3-10 Contingency Plan #3 Remediation of a leak through the cement casing



The contingency procedure consists of:

- Pull completion tubing & packer if there is a leak.
- Run electric logs to evaluate casing & cement.
- Perforate at bottom of geological seal.
- Squeeze cement into perforations to isolate leak path, and
- Install new completion tubing and packer.

The following Table 3-3 details the contingency planning for potential downhole risks.

Table 3-4 Downhole Contingency Planning and Controls

Description	Example	Response	Timing
High HSE risk with gas and/or loss rate of fluids beyond manageable containment. A barrier is severely degraded or failed.	**Surface** Sustained leak of well fluids. Destructive fail of stuffing box seals on beam pump well resulting in spill to cellar. **Downhole** Detect failure of the injection well's cement sheath in the geological seal. Average CO_2 levels in PM wells exceeding tolerances for carbon steel completions.	**Surface & Downhole** Shut down well operation. Isolate leak if safe to do so. Advise Operations Manager. ERP activated if required. Complete HSE Incident report and input into Field AIR for actions. Report to Authorities if reporting limits are exceeded. Implement remediation workover operations.	**Immediately** Repair/replace barrier.
Extreme HSE risk due to well control incident. All barriers are severely degraded or failed.	PM wellhead loss of integrity and well is free flowing at surface uncontrolled with no artificial lift.	Shut down field operations. Isolate leak if safe to do so. Design to consider downhole safety valve. Advise Operations Manager. ERP and Corporate ECMP activated. Complete HSE Incident report and input into Field AIR for actions. Report to Authorities if reporting limits are exceeded. Implement Well Control Response Plan.	Immediately kill well and repair /replace barriers.

3.21 Work force site management and accommodation

3.21.1 Construction Workforce

Bridgeport will utilise a workover rig and competent rig crew that meets all regulatory requirements to operate plant in Queensland. Additional specialist labour for other aspects of the CO_2 infrastructure construction will be required. It is envisaged that much of this will be sourced locally, depending on the activity levels in SW Queensland. Some specialist labour may need to be sourced interstate and overseas. Skilled labour is required for:

- Specialist drilling services (mechanics and fitters from wellhead and tubular companies),
- Cryogenic CO_2 storage tank, and pump package fabrication, installation, and commissioning (mechanics, fitters, electricians, instrument techs, engineers from manufacturer),
- Unloading bay fabrication, construction, and commissioning (builders, mechanics, instrument technicians),
- Flowline fabrication and installation (fitters, Instrument technicians), and
- Control and shutdown panel development (electricians, instrument technicians, telecommunication engineers)

It is anticipated the workforce (if drilling and construction is combined) could be up to 40 people at site during the construction phase.

3.21.2 Operational Workforce

. While the injection operation will be mainly automated (controlled by SCADA) a site operator will be required to monitor all operations, such as:

- CO_2 unloading,
- Existing and future return water operations,
- Gas rate and CO_2 measurement monitoring,
- Routine checks of key flows, pressures, temperatures, and overall systems management,
- Maintenance and functional testing of mechanical, structural, electrical and instrumentation

The workforce will include contractors for initial construction, monitoring, audits, and specialised maintenance tasks. Periodically, interested parties, investors and specialist CO_2 sequestration project teams may visit the site.

3.21.3 Accommodation of Workforce

Onsite staff will be housed in existing Bridgeport owned accommodation at the existing Moonie Oil Field facilities with any overflow during peak periods to local accommodation in Moonie, Tara, or Dalby.

3.22 Waste Management

In general, wastes are managed through the deployment of the Bridgeport Operations Environmental Management Plan (EMP), and onsite Waste Management Procedures which have been written with reference to the Environmental Protection (Waste Management) Policy 2000 (Qld) and the Waste Reduction and Recycling Act 2011 (Qld).

3.22.1 Sewerage Waste

Sewerage waste will be managed within the existing environmental licence conditions of operation.

3.22.2 Regulated Waste

Existing facilities are in place for the collection, temporary storage, and removal of regulated waste from site by a licenced contractor, this will be extended to this project.

3.22.3 Other Waste

Other wastes are managed in accordance with the Bridgeport EMP as discussed above.

3.23 Ancillary Activities

In addition to the activities listed above, the development is required to be supported by, but not limited to, the following ancillary activities.

3.23.1 Access Tracks

The Moonie Oil Field is a well-developed brownfield site with existing access roads (bitumen to the production facility) and graded roads to the wellheads and pipelines. Wherever possible these roads will be used. A relatively small extension of the M27 injection well site will be needed for a heavy vehicle turnaround for future ongoing CO_2 delivery and for siting of the injection skids and CO_2 storage tank. This area will be fenced off once constructed.

3.23.2 Laydown areas and office areas

The existing laydown areas between the production facility and the accommodation will be used to support the shipping in of the plant equipment and materials prior to siting at the M27 injection site and final installation and commissioning.

3.23.3 Engineering Activities

The following detailed engineering and integrity validation activities, including finalising equipment design and specification and issue of tender packages will occur,

- Engineering works associated with the construction of the proposed initial injection project infrastructure such as the CO_2 unloading facility and storage tank.
- Fabrication of the injection skid and CO_2 cryogenic storage tank under an EPIC contract
- The siting, assembling, and construction of metal products and pipework within the pilot plant project area surrounding Moonie 27,
- Workover of the M27 well to install a CRA alloy packer and tubing in and the well head,
- When CO_2 appears at the PM well similar workovers will occur

All equipment ordered and fabricated will be in accordance with API standards for CO_2 service with the relevant manufacturing controls during the construction stage, assembly and installation activities will be undertaken in accordance with the Bridgeport Safety Management System (SMS), project developed procedures and the EMP.

3.23.4 Site Security

Access to the pilot plant is restricted as it is located on the western side of the oil field with the only access through the Moonie Oil Field infrastructure. Site access will necessitate reporting to the Moonie office and undertaking personnel checks and inductions process prior to any access to the injection site which will be limited to authorised personnel.

3.23.5 Communications and Power Infrastructure

Communications and power generation infrastructure already exists as part of the Oil Field operations. It is a necessary part of Bridgeport's infield production oil well monitoring program such as data and voice communications into remote areas where Bridgeport is working.

Electricity is generated within the Moonie plant fuelled by gas or crude oil produced from the existing oil wells. This system will be used to supply electricity for the CO_2 pump and associated instrumentation and controls. This may be complemented by electricity generated by solar panels for local wellhead functions or indeed for powering the site during daylight hours, subject to the economics of a solar package.

In general, the power for SCADA communications is generated by solar panels at the well head.

Temporary power generation will be required during initial well workover operations and any subsequent rig based well intervention operations (though these are not envisaged). This power will be accessed from two temporary standalone diesel generator as part of the rig package, and located near the works being proposed and is authorised under the existing EA.

The communications systems are used for:

- Radio communication for emergency response management,
- Day to day operations and maintenance activities,
- Data communication for the collection of Supervisory Control and Data Acquisition (SCADA),
- from remote well sites and facilities for gas and water control purposes, and
- Communication for construction personnel working in remote areas.

Construction communication requirements are generally focused on current available telecommunications items such as:

- Mobile (wireless) communications (e.g., mobile phones, two-way radios) and
- Temporary office facilities providing network and internet connectivity for remote or well-site telemetry with low bandwidth requirements.

Operational requirements are generally the same as construction requirements. Installation is permanent and fully supported and includes:

- Mobile (wireless) communications (e.g., mobile phones, two-way radios);
- Existing permanent office facilities that provide network and internet connectivity; and
- Remote and well-site telemetry with higher bandwidth requirements.

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 4: Plug & Abandonment, Surface Rehabilitation & Handover

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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4.0 Executive Summary

The intent of this chapter is to document the existing regulations and practices that are in place to manage the process of petroleum well plug & abandonment, surface rehabilitation and site handover so it meets the requirements of the government and society. These regulations and practices are applied to and are appropriate for wells that inject or produce CO_2.

The overall plug and abandonment of a petroleum well is closely controlled through Petroleum Industry regulations[1] and the application of the Qld. government Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, section 3.16: well abandonment. On the Moonie site the process is managed through the application of Bridgeport's Well Integrity Management System (WIMS).

It is a statutory requirement to comply with the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland, Version 2, 16 December 2019 (Code of Practice).

The Code of Practice was compiled by the Petroleum and Gas Inspectorate with significant input from Queensland petroleum lease operators and stakeholders.

The production life of the Moonie wells may follow one of the following paths at the end of the EOR Initial Project:

- Cessation of all CO_2 injection operations and resumption of normal oil production operations at Moonie under the existing permit while the oil production is economic (the year 2040 at current oil prices); or
- Full field CO_2 EOR project is implemented, injecting up to 1million t.p.a, subject to regulatory approvals, and oil production operations at Moonie continue under that approval while the oil production is economic (the year 2050 at current oil prices); or
- Full field CO_2 EOR project is implemented, subject to regulatory approvals, oil production operations at Moonie continue under these approvals while the oil production is economic

[1] In Queensland, petroleum and gas safety is regulated under the Petroleum and Gas (Production and Safety) Act 2004 (P&G Act) with the main subordinate legislation relating to safety being the Petroleum and Gas (Safety) Regulation 2018 (P&G Safety Regulation).

(2050). Then at this stage oil production ceases, the tenement is transferred to the GHG Act and full CO_2 Sequestration is implemented subject to regulatory approvals under that Act, until the volume of the Moonie reservoir is safely filled with CO_2 (estimated to be an additional 10 years beyond 2050).

Well integrity will continue to be managed along each path by the WIMS and the Code of Practice. At the end of the field life, the wells will be plugged and abandoned, the surface rehabilitated and at the end of production and sequestration the site handed back to the State (on or around 2060) as is any other decommissioned petroleum well and site produced under a PL in the state.

4.1 Well Integrity Management System (WIMS)

Well integrity refers to maintaining full control of fluids within a well, at all times, by employing and maintaining one or more well barriers to prevent unintended fluid movement between formations with different pressure regimes or loss of containment to the environment.

Bridgeport manages its well integrity though the well life cycle by applying its WIMS as required by the QLD Code of Practice.

The WIMS approved for use by Bridgeport in Queensland outlines the key elements of well integrity, such as barriers and their operating envelopes, and the risks and threats to barriers and the management of these. It also outlines detailed well integrity data gathering activities, and initiation, approvals, reporting and responsibilities for these.

The WIMS requires the monitoring of the composition of well fluids and conditions of temperature, pressure and flow so as to identify and manage any integrity issues and these well parameters are reviewed by disciplines such as Production Chemistry, Flow Assurance and Corrosion Engineering. The Petroleum Engineer is consulted to review any changes to well design operating conditions during the well lifecycle to allow consultation with specialist engineering services as required.

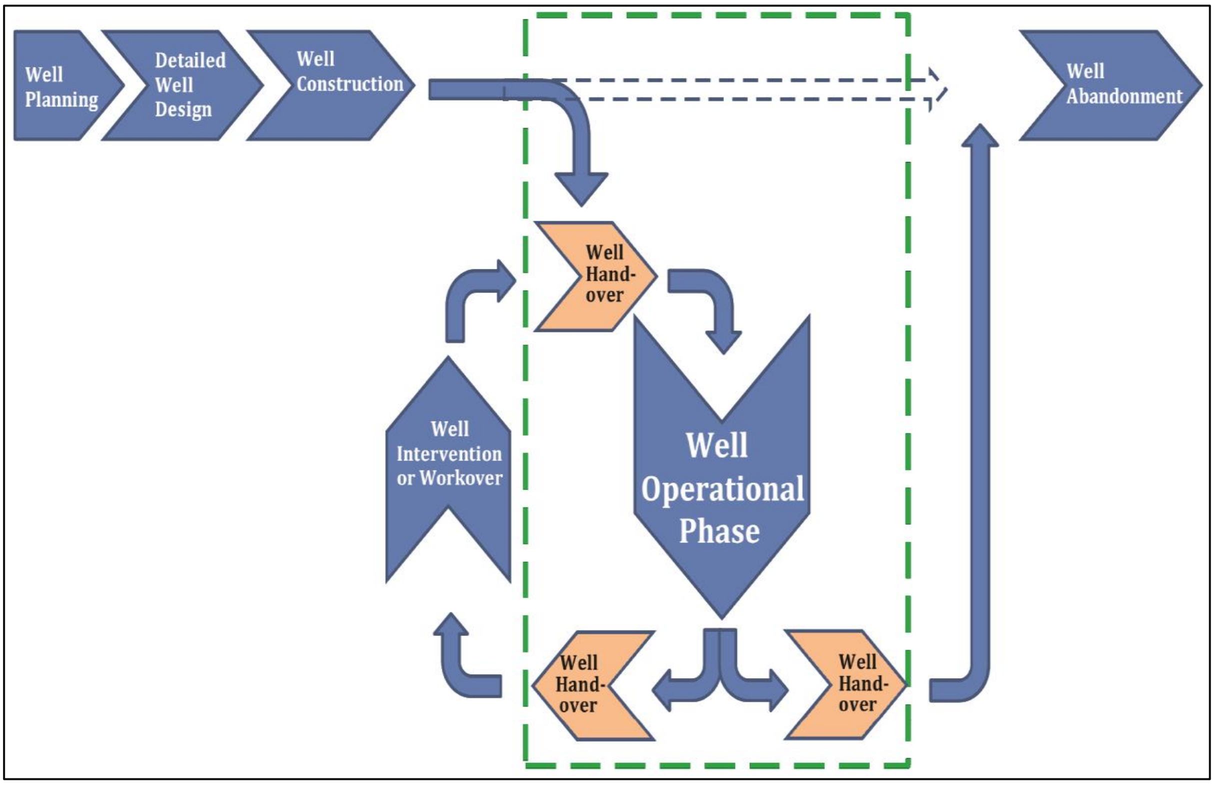
The condition and composition of reservoir fluids, annulus fluids and treatment fluids (i.e., corrosion inhibitor) is always known and compared to the well design operating envelope. Prevention of corrosion and erosion is critical to maintaining well systems in good condition.

The six stages of a well life cycle are defined by Bridgeport, in alignment with ISO 16530-1: 2017 as:

- Well Planning
- Detailed Well Design
- Well Construction
- Operational
- Well Intervention or Workover
- Well Abandonment

The following Figure 4-1 illustrates the application of the WIMS process

Figure 4-1 The overall WIMS Management Process



The Moonie wells are currently in the Well Operational Phase. If the functionality of a well needs to be changed for CO_2 injection or production purposes, then the well will be managed by the Well Workover Phase and then returned to the Well Operational Phase. At the end of the oil field's economic life, then the Well Abandonment Phase is applied.

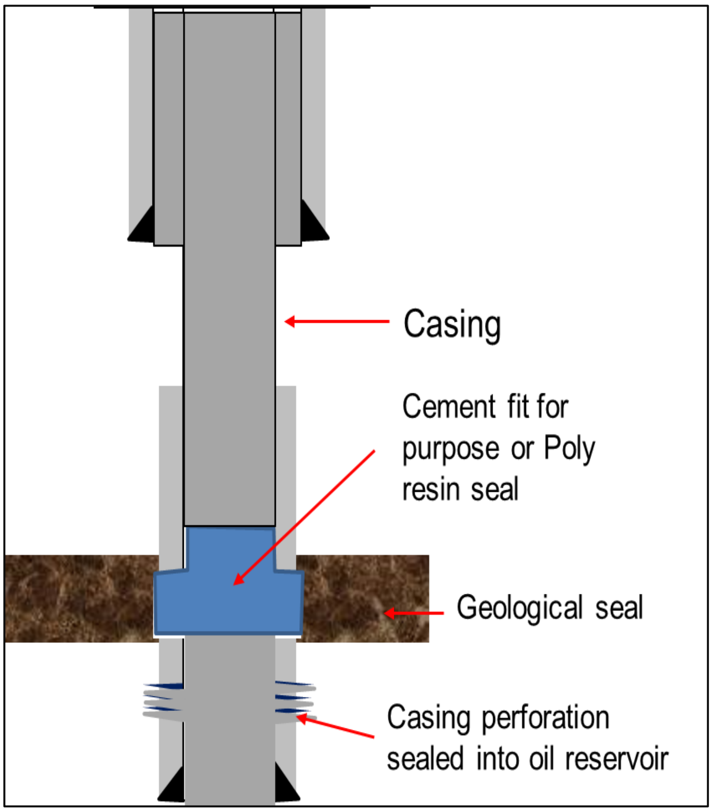
4.2 General Plug & Abandonment Process

The Qld. Regulations and the Code of Practice clearly state what is required to be assessed, performed and verified in order to plug and abandon a petroleum well. The following is a general description of the process that would be applied for abandoning the CO_2 injection well at Moonie.

1. On abandonment, an assessment of the casing, cement and downhole conditions will be undertaken.
2. Usually, a period of 6 months is used to monitor the well and its conditions.
3. Based on this assessment, the choice of the final option to permanently seal the well will be taken and will be fit for purpose, meeting all regulation requirements.
4. An additional measure that will be considered, is to section mill a length of the casing and annular cement which is adjacent to the geological seal and place a new cement plug across the geological seal.

Figure 4-2 below details the insertion of the final cement plugs downhole.

Figure 4-2 Illustration of the insertion of the final cement plug.



The general steps for the plug & abandonment of the CO_2 injection well are:

- Pull completion tubing & packer.
- Run electric logs to evaluate casing & cement.
- Set cement plug across perforations in reservoir.
- Mill out section of casing and cement to expose geological seal.
- Set cement plug across geological seal.
- Set cement plugs in upper wellbore and in annulus as required by Code of Practice.

4.3 Decommissioning

At the end of the Moonie's field economic life, the wells will be plugged and abandoned, and all plant and equipment and related surface infrastructure will be removed from the site (in some circumstances surface infrastructure will remain if requested by the Landholder),

Any contaminated soils (if any) will be either remediated on site or removed to the offsite SRA for remediation.

Where the site is deemed not to be "for future use", the land will be returned to rural use or natural vegetation density, e.g., the area surrounding the well head will be returned to land capable of rural land use.

4.4 Site Rehabilitation

In consultation with the Landholder, Rehabilitation will occur in accordance with relevant EA final acceptance criteria and conditions, and the Bridgeport Rehabilitation Procedure. This Procedure provides the framework to comply with the EA conditions.

Rehabilitating disturbed land aims to ensure those sites are:

- safe to humans and wildlife,
- have a stable surface,
- non-polluting,
- the location of the exact well location being clearly identified on the surface, and

- able to sustain an agreed post-disturbance land use with maintenance requirements comparable to that required prior to its disturbance by petroleum activities, i.e., rural land use such as cropping.

Rehabilitation activities aim to reinstate the pre-disturbance land use, in consultation with relevant land holders and government departments.

Vegetation re-establishment methods are selected on a site-specific basis to reflect the agreed land use and condition to be achieved.

4.5 Rehabilitation Methodology

The rehabilitation will be undertaken post de-commissioning using the Bridgeport Rehabilitation, and Remediation and De-commissioning Procedure, with reference to the EA rehabilitation conditions. The surface site of the well will be rehabilitated with reference to compliance with the Plugged & Abandoned specifications in the Petroleum Act & Regulations (Qld.).

4.6 Rehabilitation Performance Criteria

The rehabilitation performance criteria are listed in the EA conditions.

4.7 Final Handover

- At the completion of rehabilitation, a final sign off ascertaining the rehabilitation has been completed will be sought from the Landholder, and

- Statutory Government reports requirements will be completed, and the Government notified, prior to final formal handover to the State.

- Note that much of the land holding in the area is held by Bridgeport as freehold land (e.g., evaporation pond area and the production facility area) and may be utilised for other industrial uses at end of field life (such as solar panels for power generation).

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 5: EOR Monitoring Plan and Schedule

Commercial in Confidence

The Moonie Oil well 27 (M27)

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5.0 Executive Summary

The monitoring plan applies the physical sciences to measure the key operating parameters and thresholds to control and monitor this Initial CO_2 EOR Injection Project. It also suggests a monitoring regime to ensure the quality of groundwater in the project area remains constant with the predictions of the water model, e.g., monitoring the mean water quality of the Precipice main water leg, the Precipice oily water leg and the Evergreen water leg.

The key monitoring parameters are:

- The CO_2 volume injected versus the CO_2 volume received at the producing/monitoring (PM) wells (mass balance) and not recycled, will determine the total CO_2 sequestered volume,
- The wellbore pressure near the CO_2 injection point and the pressure in the annulus of the producing/monitoring (PM) wells,
- The wellbore temperature near the CO_2 injection point,
- The gas composition (including CO_2 levels) from the PM wells,
- The pH of the field’s produced water,
- Field’s produced water quality parameters, and the
- Gas to Oil Ratio (GOR) for the PM Wells.

The Basis of Design process will be used to determine the operating thresholds and subsequent whole of project monitoring regime. The design process will include a HAZMAT study, a HAZCHEM study and a HAZENVID study to examine the risk and subsequent physical control thresholds to monitor, e.g., the monitoring of wellbore pressure (see Chapter 11). An engineering review of the project to determine the equipment that meets the appropriate strength and metallurgy properties required as well as the control and monitoring systems (see Chapter 3 and 14).

5.1 Introduction: Initial CO_2 Project Monitoring Plan

5.1.1 Monitoring Day to day Operations

During the Basis of Design phase, a HAZMAT, HAZCHEM and a HAZENVID study will be undertaken to ascertain the exact monitoring methodology to be fit for purpose.

To effectively monitor the injection and storage of CO_2, the following monitoring methodology will be installed and operated (see Table 1 below):

- The injection wellheads and production/monitoring wellheads and related infrastructure will have pressure monitored to track the delivery, storage, and injection of the CO_2 throughout the infrastructure into and from the reservoir; the monitoring frequency will be formalised through the above studies,

- Cement bond logs (CBLs) will be initially performed as part of the initial validation of the Injector well M27 and during workovers for PM wells to validate the integrity of the cement sheath surrounding the pipe in key sections above the reservoir,

- Pressure gauges will monitor closed annulus volume conditions of PM wells in the field at regular intervals, and with further analysis if required,

- To determine any change in the GOR, a regular gas analysis will be conducted on the gas produced from each PM well to measure and monitor the production of CO_2 in produced gas. This measurement will be used to determine the position of the CO_2 cloud, the volume of CO_2 being sequestered, a validation of the CO_2 injection modelling, the efficiency and effectiveness of the CO_2 injection project,

- Gas detection will be performed in the near vicinity of each PM well, the separator, storage and generator, to identify fugitive gas if present and

- A material balance of injected and recovery fluids in line with good oil field practice will confirm the volume of CO_2 sequestered, and

- Far field monitoring of pressure to occur at wells identified below,

5.2 Location of PM Wells

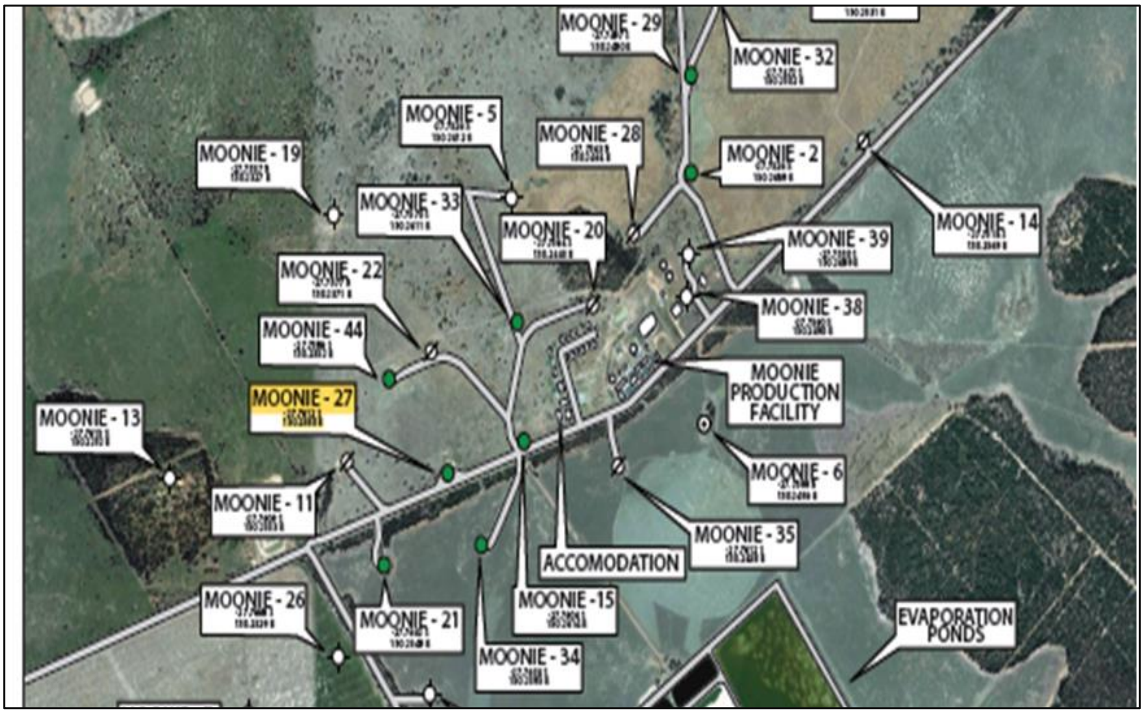
The existing wells which immediately surround the M27 well location will be considered as candidates to be a producing/monitoring (PM) wells that will be monitored to verify the CO_2 EOR process. The probable PM Wells include:

- Moonie 21,
- Moonie 34,
- Moonie 15,

- Moonie 33,
- Moonie 44, and
- Moonie 22 and 11 may be brought back online.

Figure 5-1 below illustrates the location and spacing between the PM wells.

Figure 5-1 The location of producing/monitoring wells at Moonie (green highlight)



5.3 Location of Far Field Monitoring Wells

Nonproducing wells will be used to monitor the height of the water column in the production casing annulus to detect and track any changes in the Precipice reservoir pressure. The far field monitoring wells include M3, M46, and M35

5.4 Groundwater monitoring Triggers and Thresholds

Table 5-1 details the physical environmental aspects to be monitored, their Threshold limit (to be confirmed by further risk analysis during the BOD and detailed design process), and the actions to be taken should the thresholds be exceeded, including the shutting in of a well, and activating the Contingency Plans detailed in Chapter 3.

Table 5-1 Monitoring Aspects, Triggers, Thresholds and Management Actions

• Physical Aspect to be Monitored	Analyte	Threshold	ction to be taken if exceeds threshold
Volume (m^3 or tonnes)			
	The Volume injected at Injection well	≥ 120,000 tonnes p.a.	Reduce volume injected until below threshold value
Pressure (kPa or psi)			
	Estimated Injection Pressure thermally adjusted and depending on casing or tubular yield pressures,	>11,380 to < 39,388 or >1,605 to <5,712	Reduce injection pressure so it is within threshold injection pressure, if this can't be controlled then shutdown the well
	Reservoir Pressure at production well	≥16,550 kPa or 2,400 psi	Reduce injection pressure and/or reduce volume being pumped, , if this can't be controlled then shutdown the well
	Monitoring Water column height in production casing annulus of PM wells and Far Field Monitoring wells	If the water in the annulus increases by 10% of well depth	Reduce injection pressure and/or reduce volume being pumped
	Annulus Pressure in closed volume	≥10% over original measurement	If injection well stop injection & investigate. Option to assess casing condition use contingency plans in Chapter 3. If production well shutdown assess use contingency plans in Chapter 3.
	Water column height in Far Field	1m over existing water levels and subject to weather conditions and local drawdown if any.	Rerun the model with latest data to verify latest conditions and location. If model confirms an outlying situation shutdown until the

Table 5-1 Monitoring Aspects, Triggers, Thresholds and Management Actions			
• Physical Aspect to be Monitored	Analyte	Threshold	ction to be taken if exceeds threshold
			loss of containment is confirmed.
Temperature °C			
	Temperature at the injection wellhead,	≥ sufficient to enable $scCO_2$ phase condition downhole or effect well integrity	To be calibrated with engineering process
	Temperature of the downhole tubing in injection well,	≥ 10^{O}C (may change subject to trial)	Shutdown well and assess, consider contingency plans in Chapter 3.
Gas to Oil Ratio (GOR) (%)			
	The Gas composition at receiving producing wells,	If GOR increases by 25%	Rerun the model with latest data to verify latest conditions and re-examine perforations of injector well and subsequent flows.
pH, (the concentration of hydrogen ions measured as pH)			
	pH of injected fluids	≤ 6	Refer to supplier
	pH at PM wells	≤ 4.3	Shut down wells and assess
	pH at far field monitoring wells	≤ 4.3	Shut down wells and assess
Existing produced water analysis suite			
	Standard groundwater analysis	Current licence conditions	If exceeded, notify DES using existing processes and discuss licence conditions* see note below

5.5 Monitoring for contaminants in Groundwater brought to site

The existing quality sampling regime for produced water will continue to be applied to groundwater brought to surface. The existing EA allows for the disposal of all water via evaporation so any contaminant (if any) will be contained within the existing evaporation dams. The quality of receiving waters will be monitored and recorded as per existing licence conditions.

5.6 Suggested Departmental planning and notification warnings for other external activities.

- The geology of the Moonie Anticline covers a sub-surface area of approximately 4km by 16km. For the immediate Moonie Oil Field surface area, the following restrictions are proposed:
  - Water bores: no water bores into the Evergreen and Precipice oil reservoirs.
  - Oil & Gas activities: no restriction other than to refer to Qld. Dept of Resources records for well locations and details prior to drilling.
  - Mining: open cut or long wall operations are considered to be uneconomic above the Moonie anticline. For surface mining the amount of overburden to be extracted is in excess of any current or foreseeable overburden to resource depth ratio. Given the relatively small Moonie oil field footprint no economical mining or long wall activity is foreseeable or should not be allowed over the footprint of the Moonie Oil field.

- A draft Moonie Oil Field Initial Project Monitoring Schedule is detailed in Table 5-1 overpage, please note this will be subject to completion to the various project studies mentioned throughout this document.

Table 5-1, Moonie Oil Field Initial Well Monitoring Schedule

Table 5-1 Monthly Well Monitoring Schedule									
Monitoring Item & Location	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**
M27 Injection Well									
Volume Injected CO_2									
Pumping pressure									
BHPressure									
Pumping Temp °C									
BHTemp °C									
Annulus Pressure									
For each of the Production/Monitoring Well.									
WELL NAME									
Oil/water Volume Produced									
Flowing tubing head pressure									
GOR									
Fugitive at surface gas/CO_2, if present									
Annulus Pressure, if									

Table 5-1 Monthly Well Monitoring Schedule									
Monitoring Item & Location	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**	**Month**
downhole packer									
Annulus Fluid level, if no downhole packer									
Stroke rate if beam pump well									
Hz & Amps if ESP well									
ESP intake pressure, if gauges present/working									

Table 5-2, Quarterly Reporting

Table 5-2: Quarterly Reporting
Overall efficiency of the injection program against baseline and model forecasts
Relative position of the CO_2 plume within the reservoir against the reservoir model forecasts
At the Injection well: recordings of the volume, pressure, and temperature of injected CO_2 (Table 5-1)
PM wells: changes in production flow, changes in well pressure, change in normal CO_2 levels and the gas composition of producing wells.
Ongoing water quality testing of associated water being discharged at evaporation ponds.

Table 5-3, Annual Reporting

Table 3: Annual Reporting
Estimated volume of Scope 1 & 2 emissions including CO_2 gases vented from production operations and the volume of CO_2 sequestered vs released.
A yearly summary of the monitoring program
Overall efficiency of the injection program against baseline and model forecasts
Relative position of the CO_2 plume within the reservoir against the reservoir model forecasts
A forecast of the next year's production

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 6: Geology & Geomorphology

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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6.0 Executive Summary: Regional Geology and Geomorphology

This Chapter describes the regional geology of the study area and the Surat Basin. This includes the depositional history of the Surat Basin, the underlying Bowen Basin, the stratigraphy, the geo-tectonic history, the structural geology, the anticline structure of the oil reservoir and the depositional history of the Precipice Sandstone.

The geological reasons why the Moonie Oil Field is considered to be an excellent choice for EOR petroleum activity is:

- It is located in a geological anticlinal trap considered to be 90 Ma years old.
- Stable cratonic setting – low incidence of earthquake activity.
- Low relief anticlinal structure with proven gas, oil, and water trap integrity.
- Precipice oil reservoir is well isolated from shallower aquifers.
- Top seal provides vertical closure (Rodger et al. 2019 UQ),
- Moonie-Goondiwindi fault provides a lateral seal on the northwest flank.
- No further faulting has been observed seismically or through drilling.
- There is no evidence of vertical “gas chimneys” (survey completed by U of Q),
- The minerals, carbonates and clays present react and reform to a cementing seal when exposed to mild acid, and
- Relevant existing well infrastructure in place.

6.1 Introduction

The Surat Basin of eastern Australia, contains 2,500 km^2 of Early Jurassic to Cretaceous (Albian) sediments, covering central southern Queensland and central northern New South Wales. Terrestrial deposition was relatively continuous and widespread during the Jurassic; however, two marine incursions took place during the Early Cretaceous. The sequence is almost flat-lying, and the gentle basin-ward dip is modified by drape or compaction folds and faults.

Deposition in the Basin commenced with the onset of a period of passive thermal subsidence of much of eastern Australia. It began during the Early Jurassic as fluvial to lacustrine systems depositing, fining-upward megacycles, each more than 100 m thick. Towards the end of the Middle Jurassic, fluvial deposition and coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued until the earliest Cretaceous. This coincided with a compressional event responsible for uplift and erosion of the whole area, with associated volcanic arcs which were active in the Middle Cretaceous. Abundant volcanic detritus (rock fragments and feldspars) suggests contemporaneous volcanism both within the Jurassic and Early Cretaceous. These produced the geological trap over millions of years for the oil and gas accumulations.

An extensive period of transgression during the Early Cretaceous (Aptian/Albian) resulted in the deposition of paralic and marine sediments, reaching a peak before a general withdrawal (regression) and cessation of sedimentation near the end of the Albian Stage. Deformation, episodic tectonism, and metamorphism with plate readjustment followed, because of the Late Cretaceous and Tertiary plate divergence of the large Gondwana mega-continent. In the Tertiary (Oligocene and Miocene) volcanic activity around the margins of the Surat Basin accompanied epeirogenic basin-ward tilting. Since then, the Basin has been relatively geologically stable. Subsequent erosion has resulted in the rocks becoming deeply weathered, with the formation of laterites and silcretes.

6.2 Moonie Oil Field Structure

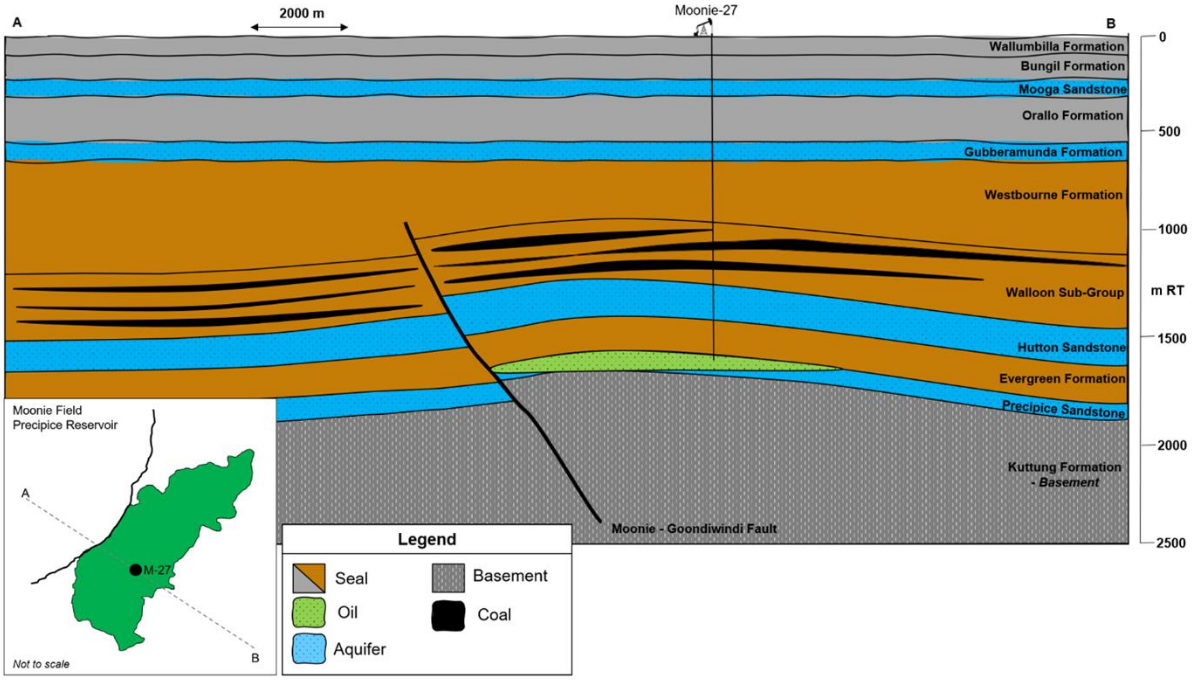
The Moonie field is located at the lower end of a south-west plunging structural nose. Deposition of sand in the Precipice had a general slope towards the north-east as evidenced by the overall thickening of Precipice in that direction. By the time of the Walloon sequence oil had migrated into the Precipice and accumulated immediately to the south of the present Moonie Field. It is trapped there due to permeability barriers and basement topographic highs of the formation. Towards the end of Walloon and prior to deposition of the Blythesdale group tilting took place such that the initial slope towards the north-east was reversed to a south-west aspect. The Moonie closure resulting in a drape structure over a basement high enhanced due to movement on the surrounding faults during the tilting episode and proved to be positioned well to trap the migrating oil. Oil is demonstrated to have been effectively trapped here and as such CO_2 will also be trapped in this structure, this is illustrated in Figure 6-1 over page.

6.2.1 Moonie Fault / Structure Map

The Moonie Field is located on the hanging wall and eastern side of the Moonie-Goondiwindi thrust fault. The Moonie-Goondiwindi thrust fault lies to the west of the oil field and is sealing[1]. An example of the fault systems is illustrated in a cross-section in Figure 6-1 overpage.

[1] An Australian first initiative to re-develop the first commercial onshore oilfield into a CO2 miscible-EOR project (Barakat et al., 2019)

Figure 6-1 Illustration of a thrust fault line



This is significant for CO_2-EOR operations of the Moonie reservoirs when employed for a full CCS project envisaged under the GHG Act. CO_2 injected during EOR operations is not expected to migrate to the fault[2].

6.2.2 The Moonie-Goondiwindi Fault System

Greater fault movement appears to have occurred to the South of Moonie and progressively younger units are displaced in a southerly direction along the fault system. Fault movement is interpreted to have terminated in the northern areas at the time of the Artesian deposition or shortly after this period. The southern area experienced fault displacement later within the Blythesdale group and possibly movement terminated within the younger sediments. Migration of hydrocarbons is believed to have initiated within the thick early Cretaceous Blythesdale Group due to its increasing thickness of overburden, overlying the Early Jurassic Bundamba Group (Evergreen and Precipice formations).

6.3 Generalised Stratigraphy of the Moonie Reservoir

Formations are described below as they were intersected during the drilling of the recent Moonie-45 well, which is correlateable across the field. A summary of the lithology and producing intervals for the Surat is shown below in chronological order as they were drilled in the well. (Figure 6-2, Stratigraphic Table for the Surat, and Bowen basins).

[2] An Australian first initiative to re-develop the first commercial onshore oilfield into a CO2 miscible-EOR project (Barakat et al., 2019)

The target reservoir lies within the Early Jurassic-aged Precipice Sandstone between 1,600 to 1,800 m below the surface and underlying the Middle Jurassic “Injune Creek” group. Formations above and below contain thick sequences of siltstone, mudstone and fine to medium grained clayey sandstone effectively sealing off lower and upper formations.

The Moonie Oil Field consists of a SW–NE oriented anticlinal structure. The reservoir consists of Early Jurassic Precipice and Evergreen sandstone formations. The deeper of the two reservoirs is the 58–0 Precipice Sandstone, located at a depth of ~1,754 metres, which overlies basement rock. Basement rock consists of Kuttang/Camboon Volcanics, with carboniferous intrusions at deeper levels.

The Precipice Sandstone is part of the Great Artesian Basin (GAB), which covers 1,170,000 km2, equivalent to 22% of the Australian continent. The GAB comprises several overlapping basins which overlay each other in which interconnectivity exists. Honaire (et al) discusses the implications of subsurface morphology in the project area in the risk assessment at Chapter 11.

The Precipice 58–0 sandstone is the main producing reservoir for the Moonie Field. The reservoir forms a part of a strong regional aquifer of amalgamated coarse grained fluvial channel sands (~40 m thick) with granitic provenance, typically fining-upwards in the upper 10 m, with an occasional abrupt upper boundary eroded by the Basal Evergreen Formation.

The oil-bearing basal sandstone in the Evergreen Formation, which lies conformably above the Precipice Formation 35m shallower at a depth of ~1,719 mKB (1447m TVDSS), comprises moderate sinuosity quartzose channels interpreted as being 200–400 m wide with high permeability lenses up to 100 m wide.

Above the Evergreen Formation is the thick (200m) Walloon Formation, which is a regional seal of a siltstones, shales and a coal deposited below 1,075m TVDSS. This is the principal seal for the Moonie Field deposited in the Middle Jurassic.

6.4 Stratigraphic column of the Surat Basin

The sediments of the Moonie oil field were deposited on the remnants of the back-arc Bowen Basin. The Moonie Field is located on the hanging wall and eastern side of the Moonie- Goondiwindi thrust fault. The Moonie Field is within the Surat Basin sedimentary sequence (Figure 6-2). The top Precipice formation is at approximately 1,699 m and up to 130 m thick. The general stratigraphy and Lithology of the Surat Basin are detailed in Figures 6-2 below.

Figure 6-2 Surat & Western Bowen Basin Stratigraphic column

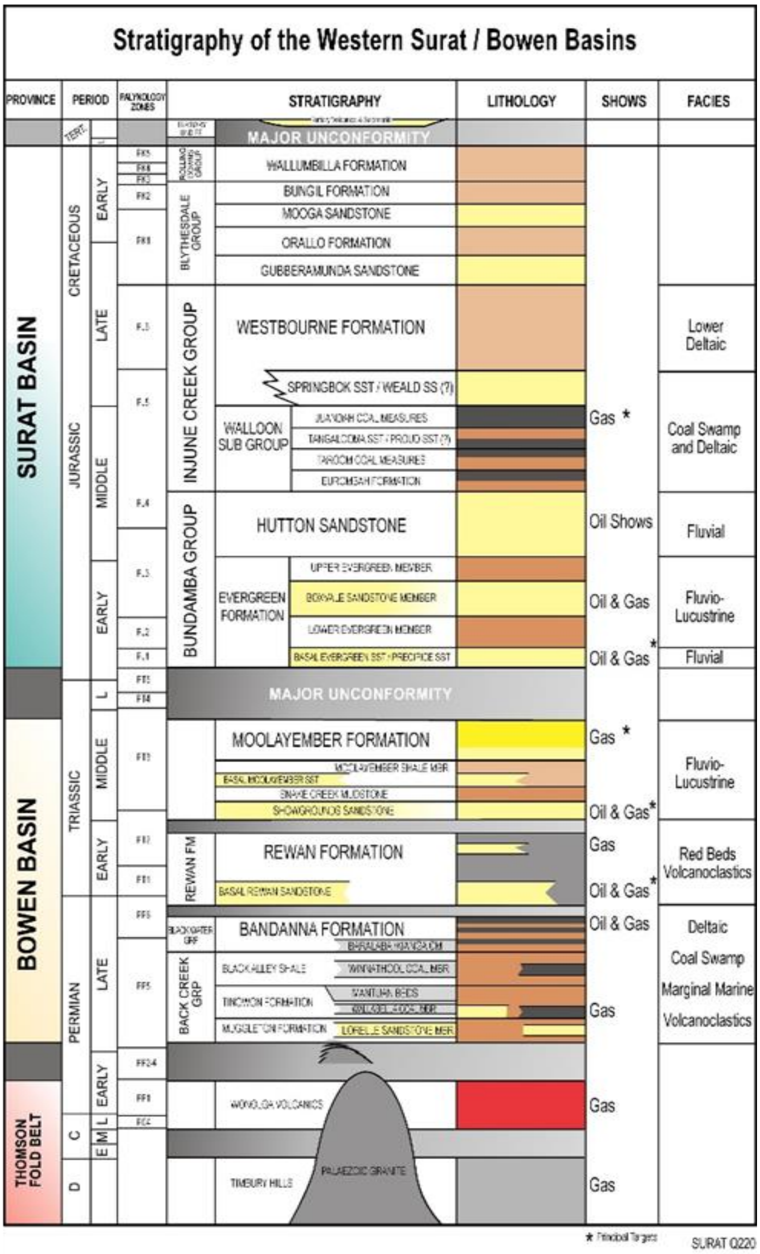


Table 6-1 illustrates the depths and thickness of the various formations in Moonie 27, derived from downhole wireline logs.

Table 6-1 Depth and thickness of various Formations at M-27

Well Name	Formation Name	Measured Depth	Sub-Sea Depth	Thickness (m)
Moonie-27	Walloon	1081	-812	304
Moonie-27	Hutton	1385	-1116	185
Moonie-27	Evergreen	1569	-1300	62
Moonie-27	M5 Shale	1632	-1363	81
Moonie-27	56-4 Sands	1713	-1444	16
Moonie-27	M6 Shale	1730.91	-1460	11
Moonie-27	Precipice	1742	-1472	17
Moonie-27	58-0 Sands	1759	-1489	29
Moonie-27	Camboon Volcanics/ Basement Kuttung	1787	-1518	0.7
Moonie-27	TD	1794		

6.5 Geological description of main formations

6.5.1 Hutton Sandstone (Upper and Middle Jurassic).

The Hutton Sandstone consists of sandstone with minor siltstone interbeds, deposited in a fluvial environment with varying depositional energy. The sandstones are clear to translucent, very light grey to light brown grey, light grey, minor pale yellowish grey, very fine to very coarse grained, with weak to moderate calcareous cement, rare to occasional white to light grey - brown argillaceous matrix, minor lithics and carbonaceous inclusions with very poor to fair visible, yet poor to fair porosity inferred as the sand are very poorly consolidated. The siltstone interbeds (overbank and channel fill) are light to dark brown grey, light to medium brown, argillaceous, arenaceous in part grading to a very fine-grained sandstone, micro-micaceous in part with trace common carbonaceous specks and inclusions.[3]

6.5.2 Evergreen Formation (Early Jurassic) 1,570-1,699 m (at M-27)

The Evergreen reservoir sandstone has been named '56–4' and is sometimes divided in to an upper and a lower unit. Together these are typically less than 10 m thick. Special core analysis laboratory (SCAL) and petrographic data shows that the geological controls on the permeability and capillary pressure are from the volcano-lithic sediments, which consist of fine to medium grained material, 35% unstable lithic fragments, 26% clay and 24% quartz. The quartzose sediments are coarse grained with 12% clay and 63% quartz. Previous correlations have shown that the gross interval of 56–4 is easily correlated, but there are high lateral variations of the high permeability quartzose facies. The formation has Interbedded and interlaminated sandstones and siltstones with minor coal.

Siltstones within the Evergreen Formation are light to dark brown grey, light to dark brown, medium to dark grey, argillaceous, commonly arenaceous, micro-micaceous in part with minor to common carbonaceous inclusions and minor lithics. The sandstones (except for the 56-4 sand) are clear to translucent, off white to light grey, light brown, very fine to medium grained, occasionally coarse grained, with weak to locally strong calcareous/siliceous cement, minor to occasional off white to light brown - grey argillaceous matrix, minor to occasional carbonaceous inclusions and lithics, and tight to poor visual and inferred porosity. The minor coal encountered in the Evergreen Formation is black to black - brown, dull to sub vitreous, silty in part with an uneven fracture.[4]

Moonie core sample average percentages:

- 63% quartz
- 13.7% carbonates
- 1.2% chert
- 8.1% feldspar
- 4.1% lithics
- 3.7% clay, and
- Visible porosity 8.1%

Carbonates include calcite cement occupied in all intergranular pore space and siderite, mostly partial replacements of feldspar grains.

[3] From the Moonie – 44 Bridgeport well Completion Report, Stratigraphy Section.
[4] From the Moonie – 44 Bridgeport well Completion Report, Stratigraphy Section.

6.5.3 Precipice Sandstone (Early Jurassic) 1,699-1,787 m

The Precipice has been subdivided into five separate units (56a to e) and named in order of increasing depth. These are 5–10 m thick but typically there are only two or three units in a well. Moreover, in many wells the total depth occurs above the base of the Precipice Sandstone and the full sequence has not been penetrated. The Moonie-Goondiwindi thrust fault lies to the northwest of the oil field and is believed to be sealing. The CO_2 injected and ultimately stored in the Precipice and Evergreen formations during EOR operations is not expected to migrate to the fault.

6.5.4 Precipice Sandstones and Siltstone.

The Precipice sandstone and siltstone are described as follows:

Sandstones are translucent to clear, off white to frosted, rare pale yellow, fine to very coarse grained, dominantly medium to coarse grained, with trace to moderate siliceous/calcareous cement, rare quartz overgrowths, rare off white argillaceous/kaolinitic matrix, rare lithics and carbonaceous specks, and poor to good, inferred porosity, poor to fair visual porosity. The minor siltstones are medium to dark grey, light to dark brown grey, arenaceous, occasionally siliceous, argillaceous in part, occasionally micro-micaceous with trace carbonaceous specks.

Core sample average analysis percentages for Precipice sandstone and siltstone.

Clean, porous, moderately sorted quartzarenite consisting of:

- 0.5% chert
- 1.0% feldspar
- 5.5% clay
- 22.5% visible porosity[5]

The provenance of this section is from well washed fluviatile (river) sands, characterised by;

- Quartzose units, composed of individual sand bodies variable in thickness and lateral extent.
- Slight, but overall decrease of grain size occurs towards the top of the sand.
- Individual sand bodies usually have a shard erosional basal contact and occasionally contain reworked fragments of shale near their bases.
- Most of sand cross stratified with angles mainly low to moderate up to 20° and occasionally as high as 30°.
- Basal portion of 58-0 sand is cleaner than the upper portion indicating reworking of original deposits in the earlier stage of deposition.

[5] *From Petrographic study of the 56-4 sand in Moonie-2 Martin, K.R. 1986*

6.5.5 Typical characteristics of the Precipice Sandstone

- Formation Pressure = 16,550 kPa
- Salinity = approximately 1,900 mg/L
- Oil gravity is between 45-50 °API
- Average porosity = 16.8 %
- Median Kh (mD) = 13 (n=1519)
- Storage Area (across the Surat basin) = 39,491 (km2), Actual project area is <40 ha which is 0.001% or less of the total available area in the Surat Basin.
- Zone of immediate effect is within 0.2 km being the approximate distance from the injection well to the monitoring well.
- Average bottom hole temperature (BHT) is 75^{o}C depending on location and depth

6.5.6 Precipice Sandstone Deposition

The Moonie-Goondiwindi Fault divides the area into an:

Eastern high block of Permian to Carboniferous rocks (where Moonie is located); This block consists of a broad subcropping around the edges of the Mimosa Syncline and the Permian rocks occupy a broad area in the centre, and

Western low block of Triassic rocks, sub-cropping beneath the Precipice Sandstone; This Triassic – low block was exposed and eroded the Permian rocks to a relatively smooth plain and reduced the Carboniferous rocks to a belt of hills and scarps. These positive features were overlaid by the more resistant beds within the Kuttung formation and one such feature lay in the Moonie field area where the Kuttung abuts against the Moonie fault.

The basal sandstone member of the Precipice covers permeable 58-0 sands. At Moonie, the 58-0 sand varies from a known minimum thickness of ~21 m to a maximum of ~60 m. The 58-0 sand is overlain by siltstones and finer tight sands indicating a decreased rate of flow/energy of the depositing medium prior to the brief resurgence of current rate which caused the deposition of the overlying ‘56-4’ sand. Following the ‘56-4’ sand deposition, the current energy waned further and the coarser clastics gave way to finer clastics and the pelites of the Evergreen shale.

The amalgamated Precipice Sandstone is inferred to be deposited from the south and west across this surface by streams forming an extensive alluvial plain. The sand was deposited in point bars and in natural levees which occurred along multichannel systems constantly migrating across the flood plain. Finer material such as shale and silt were deposited in old, abandoned stream channels and up on the interchannel areas during floods. As the channel systems migrated, reworking of the old deposits took place resulting in cleaner sands and winnowing of silty deposits.

The high areas slowed down and deflected the rivers flowing from the south and west before the areas underlain by the Permian rocks were reached. Once the currents were slowed, they dropped coarse material near the high areas and allowed finer sediments to be carried on to the flat areas of Permian, east of Moonie. These conditions had an important bearing on the ultimate trapping of oil in the Moonie structure. For the Precipice sandstone, special core analysis (SCAL) and petrographic data indicate multi-Darcy permeabilities in some units. The geological controls on the permeability and capillary pressure are from the coarse grained quartzose, grey, sucrosic sandstones. The authigenic phases are recognised as pervasive kaolin pore fills and quartz overgrowths. Previous correlations show low lateral variation and a moderate to high confidence in correlating individual reservoir units in the Precipice 58–0 sandstone.

Figure 6-3 bellow illustrates the core & well logs taken from the Precipice

Figure 6-3 Precipice sandstone well log and core

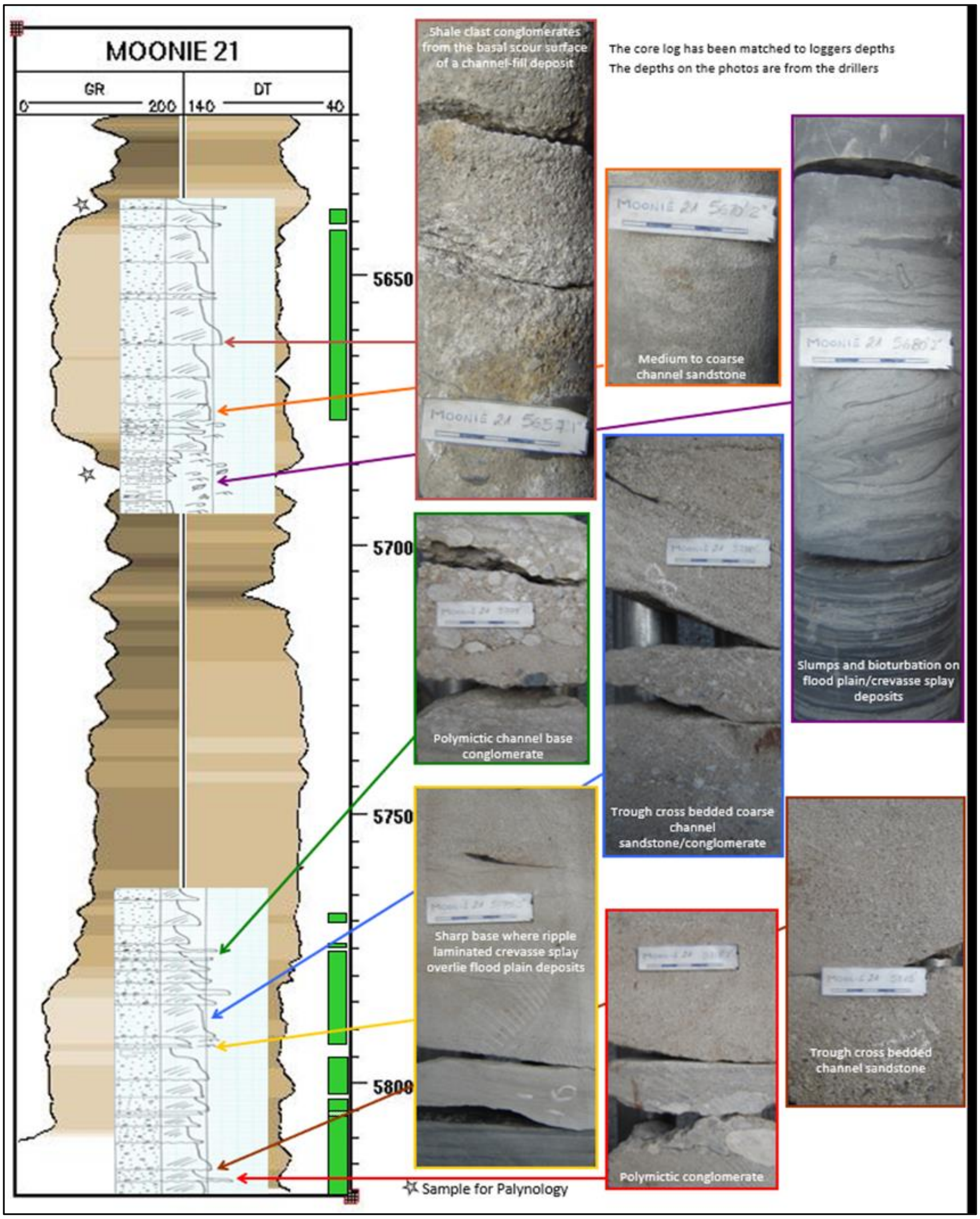
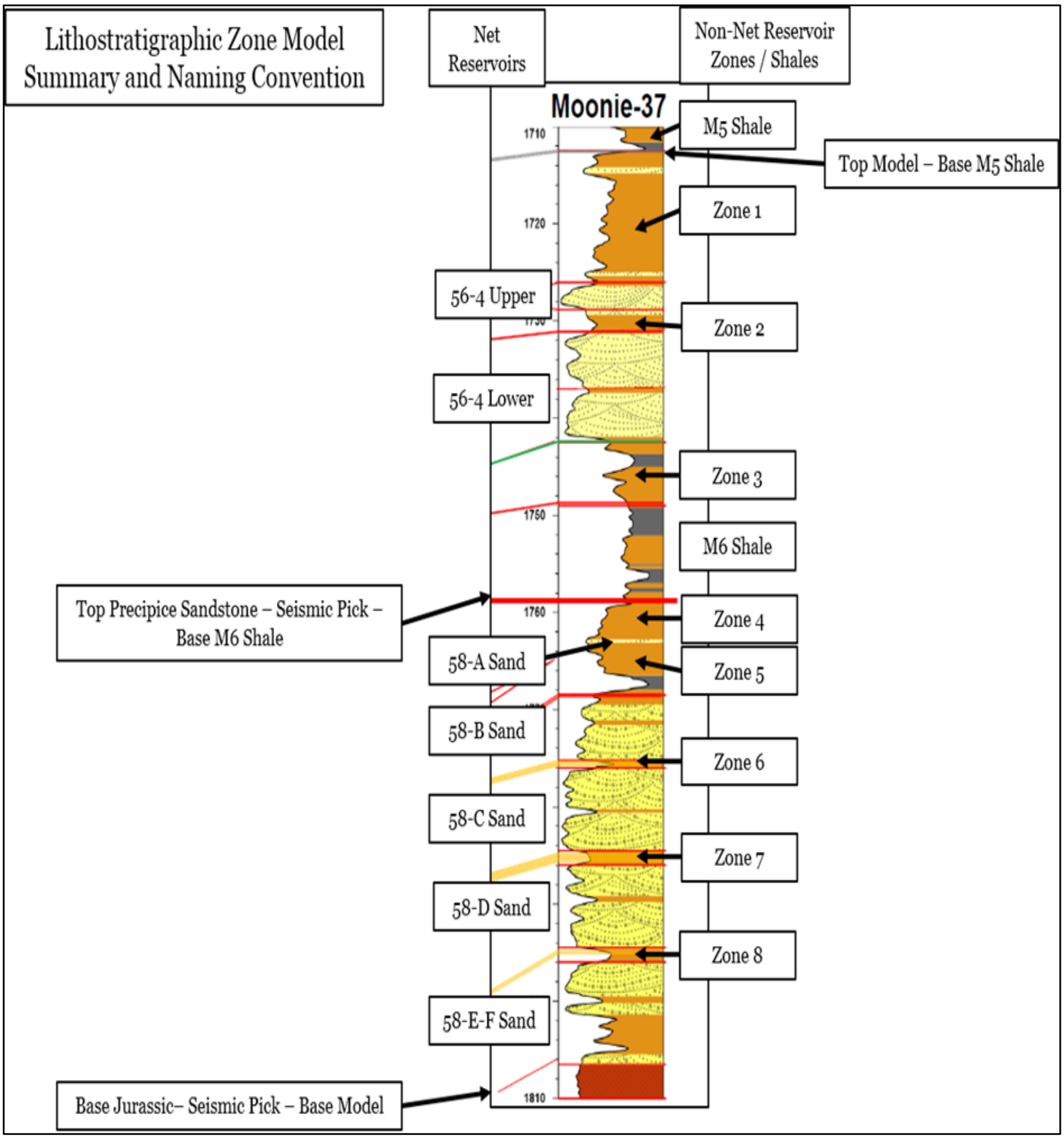


Figure 6-3 above illustrates the variable lithology over the two producing horizons. As a comparison, Figure 6-4 shows the associated seal and reservoir sections of Moonie 37. The lower formations are physically tighter due to their depth, age and chemistry with interbedded and overlying seals preventing mass migration of fluids and creating a seal for gas, oil, water and subsequently CO_2. The inter formation seals are detailed and illustrated in Figure 6-4, below.

Figure 6-4 Seals and Reservoir Units - Moonie 37



6.5.7 Basement – Kuttung / Camboon Volcanics (Permian) 1,787 m onwards (M-27)

The basement of Moonie consists of Tuff being a medium to dark brown grey, occasionally brownish-black, minor pale to medium greyish green, and is siliceous, cryptocrystalline in part with an occasional waxy texture and minor dark lithic inclusions. The sandstones are non-porous, translucent to clear, light to medium grey, fine to medium grained, minor coarse grained, with moderate calcareous cement, trace very light grey argillaceous matrix. Trace orange brown and dark green volcanic lithics, and the porosity is tight to very poor. The siltstones are medium to very dark brown grey, dark to very dark grey, argillaceous, in part occasionally arenaceous, micro-micaceous in part with green - black volcanic lithics.

The Surat Basin is one of the most prospective onshore basins in Australia for CO_2 storage. The Precipice Sandstone and Evergreen Formation have been appraised for their feasibility as a future CO_2 storage reservoir-seal pair across the basin. At the Moonie field the focus is on predicted CO_2-water-rock behaviour in these reservoirs which are constrained laterally and vertically by the shape of the Moonie Oil Field structure. Drill core samples were collected from archived well core samples at Moonie and in other parts of the basin (see Figure 6-3).

The core samples were analysed for porosity, and mineral content to build a geochemical model to predict local CO_2 water-rock behaviour and their potential effect on reservoir scaling, changes to porosity and mineral trapping of CO_2.

The Precipice Sandstone sampled in the Moonie Field has different mineralogical characteristics to wells to the North. Here, CO_2-water-rock predictions indicate minor alteration of plagioclase and K-feldspar to kaolinite, chalcedony and ankerite in cleaner Moonie sandstones, with the precipitation of smectite in clay rich sands. Formation water pH was buffered between 5 and 6 by dissolution of calcite or siderite cements. Sampled core has also shown evidence of previous natural CO_2 and hydrothermal fluid alteration, fractured quartz grains, and carbonate fracture filling with carbonates. This type of natural analogue data is vital to validate long term predictions of seal validity and self-sealing fractures. CO_2 is generally injected at >1600m depth into high porosity and permeability formations and structurally trapped under seals. At Moonie 27 the injection depth will be greater than 1,600 m.

6.6 The Moonie Core Sample Analysis – 58 sands

Pearce et al (2016-2018) conducted analysis and modelling of the available Moonie core samples across the Moonie Field to determine the permeability characteristics of the Precipice sandstone. . A Mercury Injection Capillary Pressure (MICP) analysis was performed on the Precipice Sandstone (58 sands), and the basal Evergreen Formation (56-4 sands). Pore throat distributions are broad and often bimodal in the lower Precipice Sandstone (58-0 sands) ~0.05-100 µm reflecting the lower quartz (~80%) and higher feldspar and clay content (see Figure 3-4, below, examples labelled P) when compared to Precipice Sandstone from the studied northern well cores. Wireline depth trends and basin wide geology from UQSDAAP suggest the differences reflect different depositional environments and provenance.

Quartz grains in both the Precipice and Evergreen sandstone samples were often naturally fractured, indicating that high fluid-transmissivity could be partly fracture controlled. Feldspar was also strongly denatured and altered to pore filling clays.

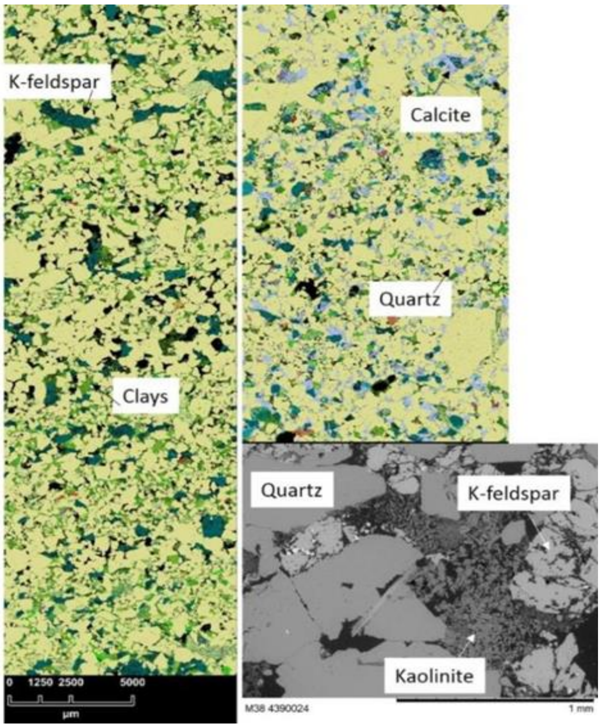
The higher Sodium -bicarbonate content formation water in the Evergreen Formation (56 sands) buffered pH to higher values, along with the dissolution of minerals.

6.7 Evidence of natural CO_2 mineral alteration.

Various core samples show evidence of natural fractures, some filled with carbonate minerals, and hydrothermal minerals that are likely related to previous CO_2 alteration from hydrothermal fluids. Examples include in the Evergreen Formation and Westgrove Ironstone member in the offset Chinchilla-4, Southwood-1 and West Wandoan-1 wells, and within sections of Moonie 22, 31, and 38 well Evergreen Formation (56 sands and mudstones). Natural fracture fill minerals include siderite, calcite, Trioxide/ilmenite, apatite, pyrite, silica, and barite which all form cements. Fractured quartz grains in the Southwood-1 and various Moonie well cores indicate potential for partial fracture flow, given the relatively high permeability in the Moonie reservoir sands (56 and 58 sands).

Natural analogue data is useful to understand processes occurring through geological timescales and essential to validate geochemical models. For example, alteration processes predicted include plagioclase and chlorite conversion to clay minerals and siderite and ankerite. This is consistent with observations in natural systems with high CO_2 content. What is also evident is the closure and cementing/sealing of micro fractures. Figure 6-5 illustrates examples of QEMSCAN images of Moonie-38 core, with potassium feldspar altered to the pore-filing clay mineral kaolinite and illite.

Figure 6-5 QEMSCAN images of Moonie-38 core



Left: Precipice Sandstone (58-0 sand) containing potassium feldspar and clays.

Right: Evergreen Formation (56-0 sand) with calcite cement filling pores.

Inset: An SEM image of the Precipice Sandstone is shown, with K-feldspar extensively naturally altered to pore filling kaolinite and illite.

In the Evergreen Formation (56 sands), in the presence of CO_2, the calcite cement dissolution at 1,727 m quickly buffered the formation water to a pH of 4.9 after 30 years simulation, 5.0 after 100 years, and 5.3 after 1000 years. The low fugacity model predicted a pH of 5.7 after 1000 years. Calcite, plagioclase and feldspar were altered to smectite, kaolinite, chalcedony, and carbonates. Sandstone from 1723.8 m (and clay-rich sandstone from 1,726.7 m) buffered the formation water to a pH of 4.9 with feldspar and siderite dissolution after 30 years, 5.0 after 100 years, and 5.3 after 1000 years. Kaolinite was precipitated in cleaner sandstones, and smectite in clay-rich sandstones and shales. Precipitation of smectite is likely to maintain or improve sealing capacities of clay-rich seals.

Figure 6-1: is a cross section and plan elevation of the PL1 Moonie Oil Reservoir situated within the Moonie anticline. This figure illustrates the location of the injection well M27 in relation to the greater oil reservoir. The anticlinal dome containing the oil, gas and water is clearly represented and is identified by a light green colour. M27 is perforated down hole to allow access to the oil reservoir within the Precipice Formation. An extensive seal exists between the top of the Precipice and in the basal Evergreen Formation.

This is further illustrated in Figure 6-6 below. The Moonie-Goondiwindi fault provides a lateral seal on the northwest flank.

Figure 6-6 Cross section highlighting the basal shale separating the sealing Precipice SS

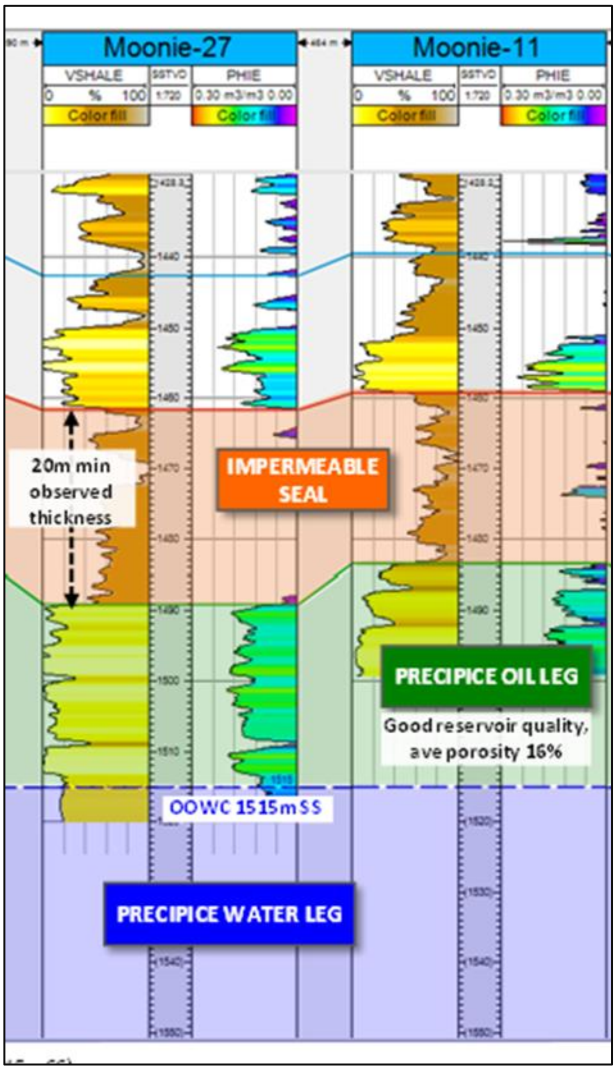
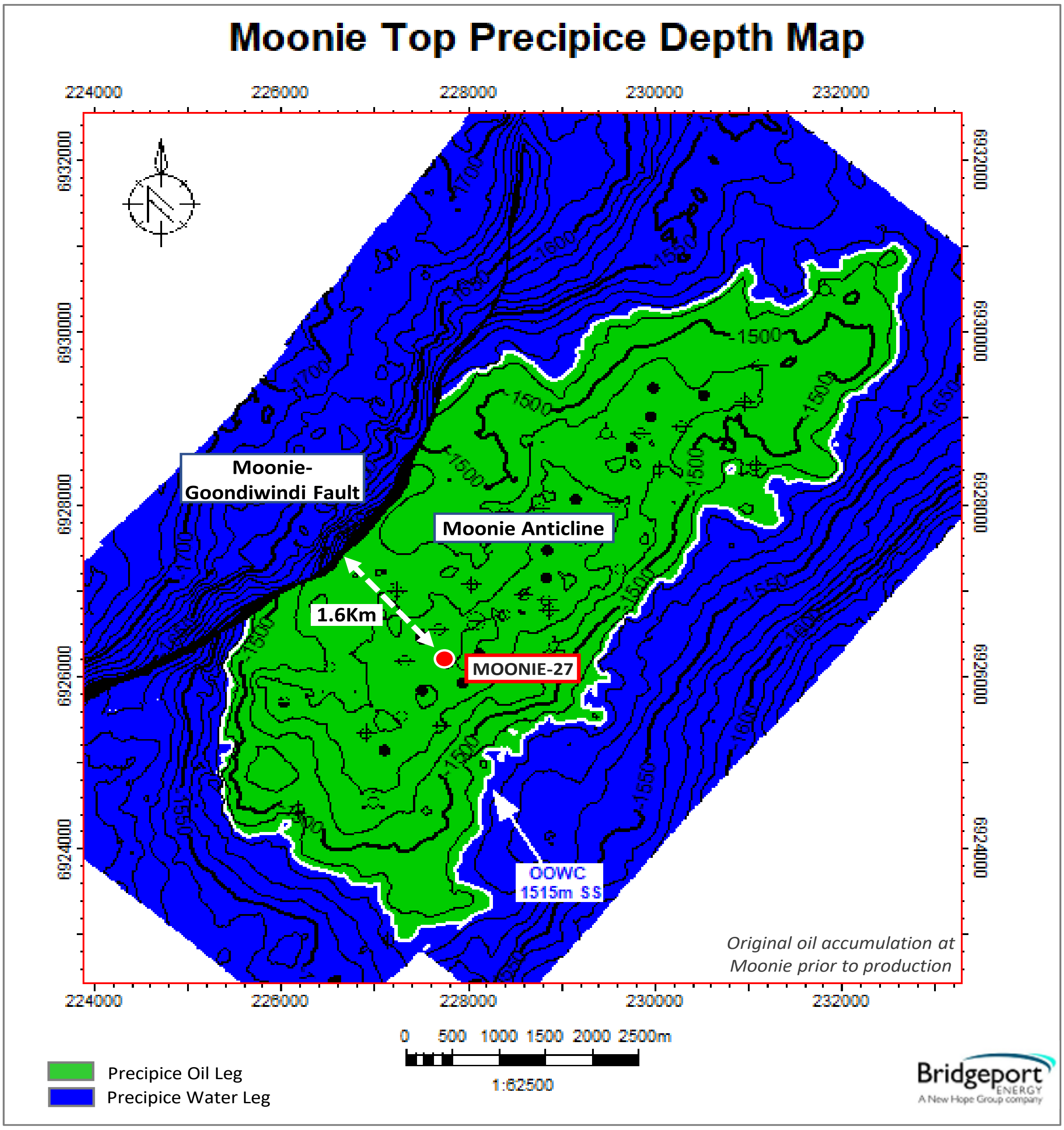


Figure 6-7 illustrates the extent of the Moonie reservoir, with an areal extent of approximately 4 km x 16 km. The location of M27 is identified by the red symbol. The Precipice sandstone 58-0 reservoir productive limits are controlled by an oil-water contact (Figure 6-8) An upper sandstone member, the Evergreen “56-4 sand” is separated from the main sand by approximately 30 m of tight sands and silts. Productive limits are controlled vertically by permeability barriers and laterally by the oil-water contact[6] with the oil having been trapped in the reservoir for 90 million years.

Figure 6-7 Moonie Top Precipice Contour and Depth Map

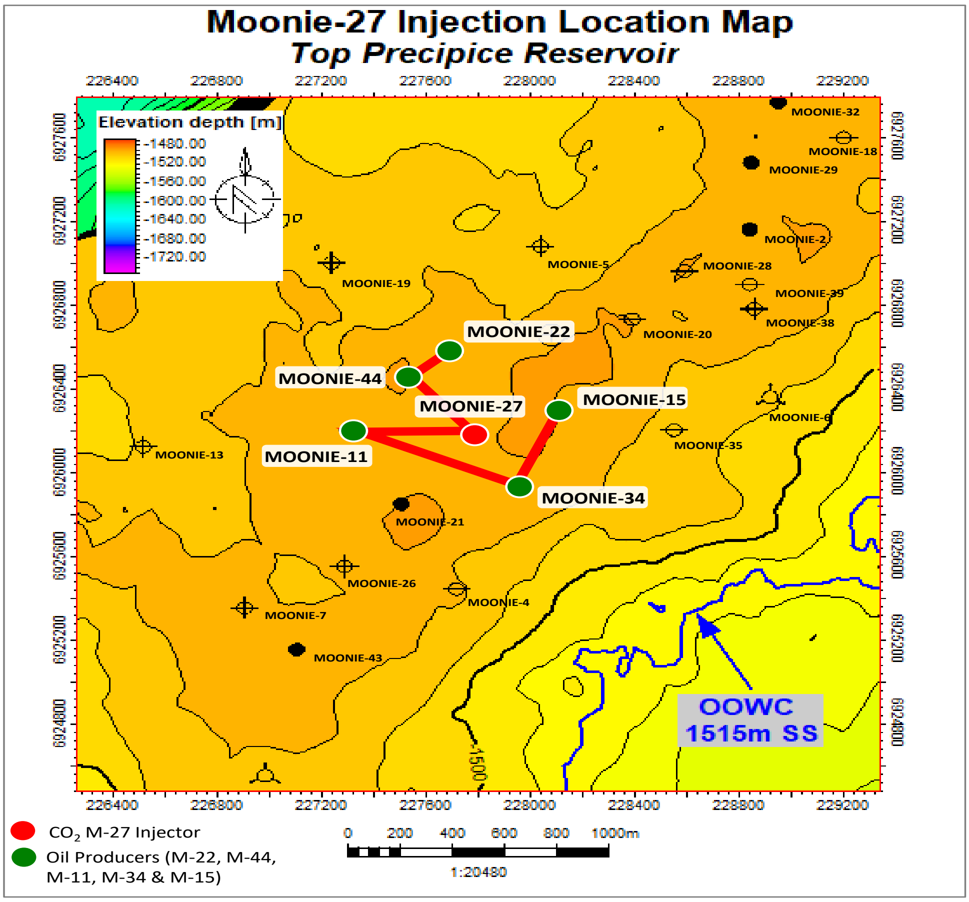


[6]From Case Histories of the Moonie and Alton Oilfields Buckley et al., 1969

6.8 Moonie Well sections: Reservoir and Seals

Figure 6-8: M27 Injection Location Map, illustrates the existing locations of the injection well M27 and the 5 flanking production monitoring wells (M22, M44, M11, M34, M15). There are also outer area production wells not illustrated that could be used if necessary, as potential candidates for outlier monitoring wells.

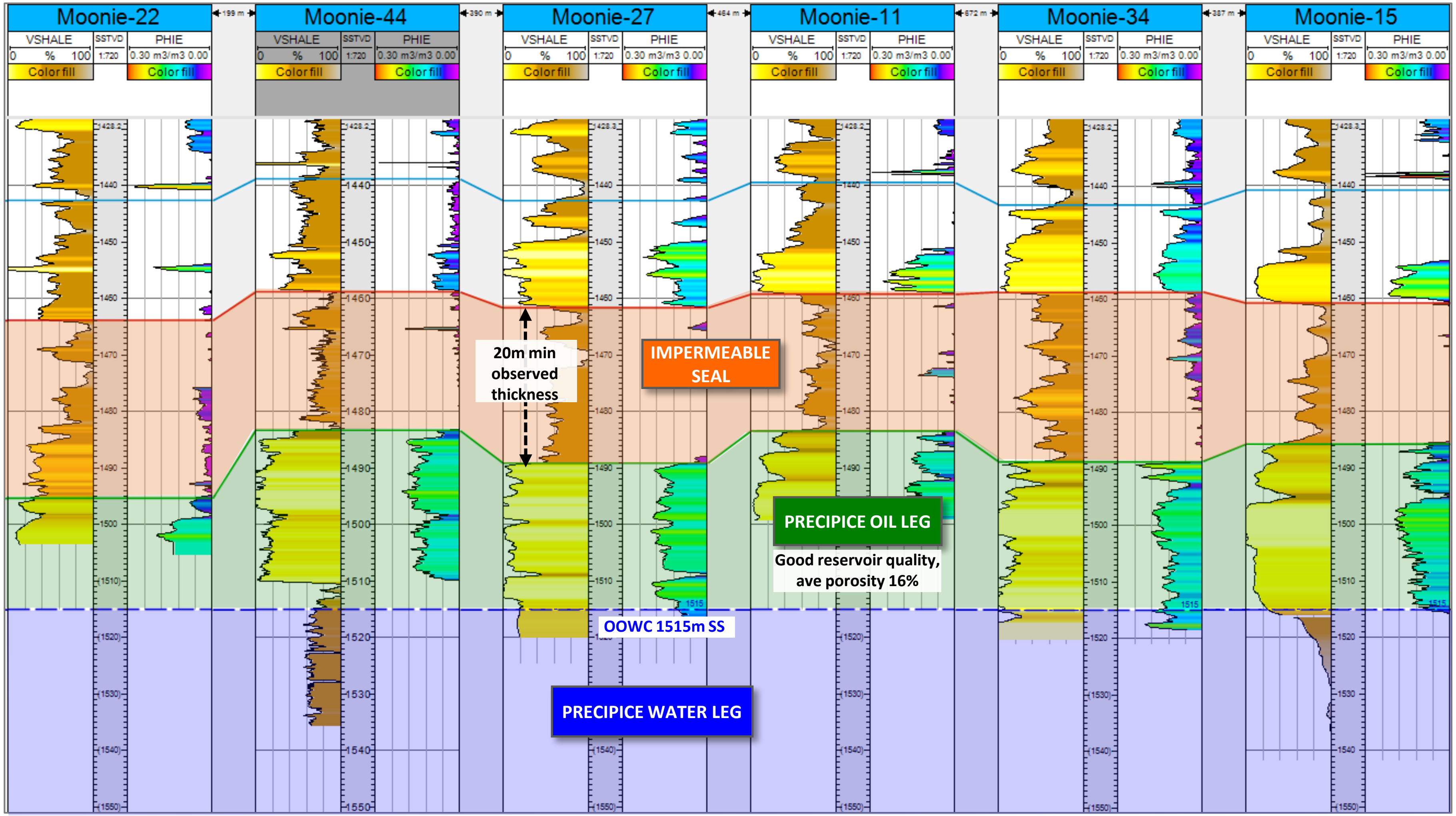
Figure 6-8 The M27 Injection well and surrounding Production Wells Location Map



The following downhole well section correlations in Figure 6-9 illustrate each PM (Production Monitoring) well. The impermeable seal shown in orange has a minimum thickness of 20m with a higher V shale content and overlies the Precipice oil reservoir with its higher effective porosity (PHIE).

The logs clearly demonstrate the difference in rock character between the Precipice oil leg and the overlying Evergreen impermeable seal. The Precipice oil leg (in green) lying below the seal, is perched above the Precipice water leg (shaded blue) with the oil water contact clearly identified as a dotted line.

Figure 6-9 The Injection and Production well sections

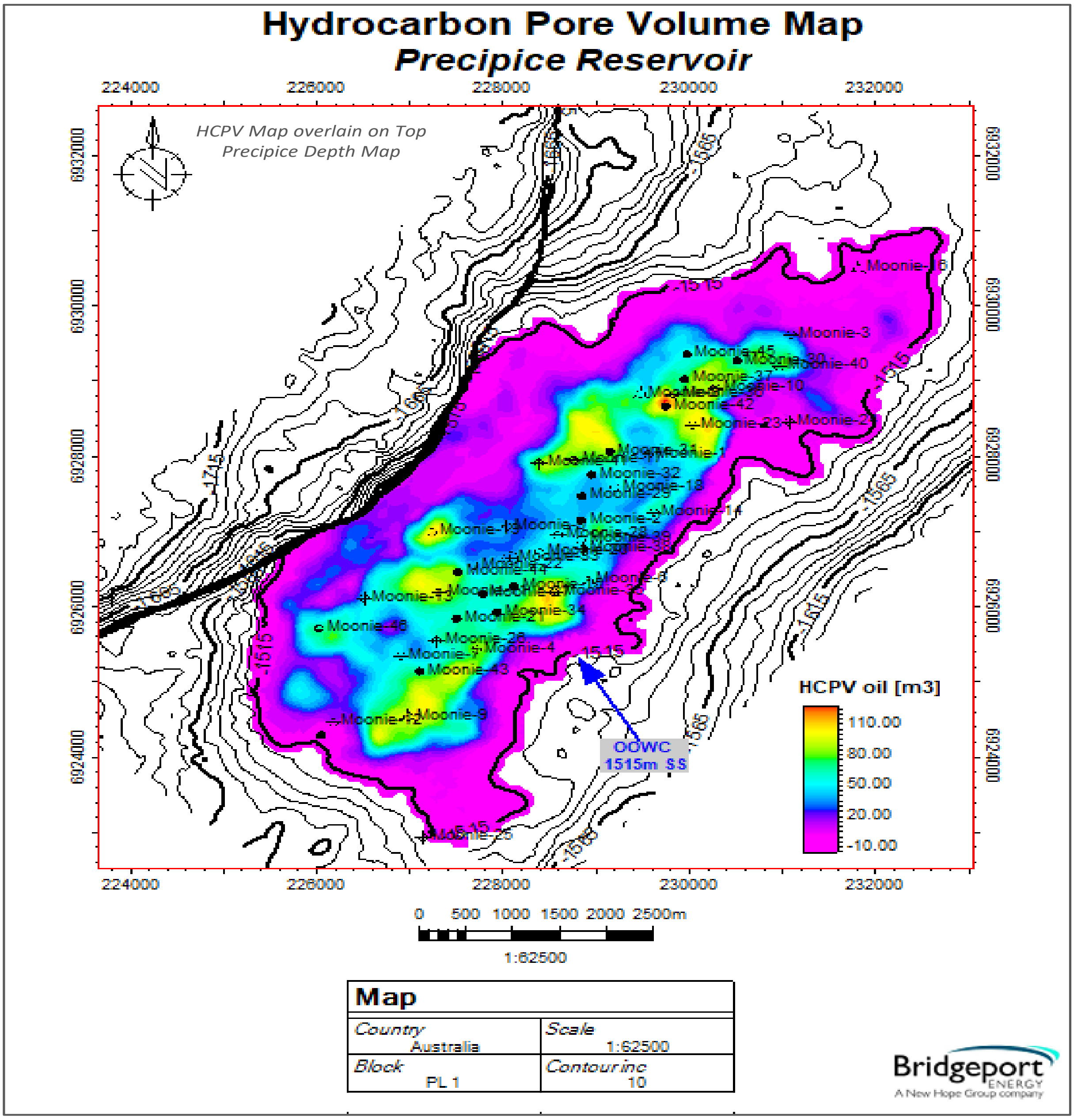


Note: S*ection flattened on original oil water contact (OOWC @1515m SS)*

6.9 The Moonie Model Trap Volumes – Original Oil in Place

The hydrocarbon pore volume (HCPV) map in Figure 6-10 below represents the model-based hydrocarbon pore volume overlain on the Top Precipice depth structure section (Figure 6-9 above). The highest pore volumes are in the structural highs of the oil reservoir. These zones are illustrated with the highest being red, then yellow, turquoise, and pink which also correspond with the highest gas grading to oil concentration.

Figure 6-10 The Hydrocarbon Pore Volume Map – Precipice Reservoir



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7.0 Executive Summary

This chapter examines the Moonie Oil Field Hydrogeology. It includes a discussion of hydrogeological topics and elements such as formation porosity, permeability, hydraulic conductivity, physical pressure and volume concepts, and water pressure gradient analysis that clearly delineate different water qualities in the "Precipice oily water leg", the overlying Evergreen and the lower main "Precipice water leg".

To date approximately 60 MM tonnes of water and oil have been extracted from the Moonie Oil Field. This project intends to inject 120,000 tonnes of CO_2 p.a. for 8 years totalling 1 million tonnes or approximately 1.7% of the extracted volume. As such no water will be displaced from outside of the anticline and as no conduit to the surface exists (apart from human intervention) as detailed by the University of Queensland (UQ), there will be no impact to surface or near surface groundwater resources.

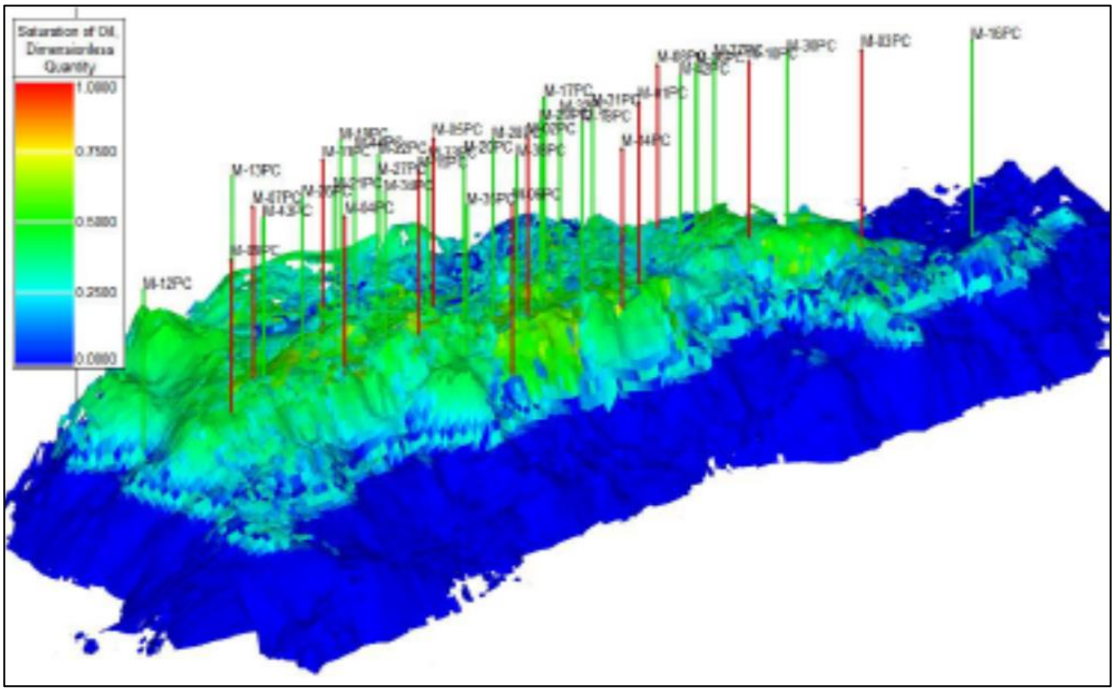
The objective of this section is to discuss the potential and modelled physical impact and aspects of injecting CO_2 into the Precipice oily water leg. Specifically, the formations surrounding the injection point at M27, 1,500m sub surface. Section 7.3 specifies a maximum temperature adjusted upper injection pressure threshold to prevent any impact on the geologic transition zone or sealing barriers.

The ultimate seal has extremely low permeability (Harfoush et al. 2019a, 2019b, 2019c and Honari et al. 2019a) with core plug measurements of horizontal maximum corrected water permeability ranging from 0.003 to 0.086 mD (arithmetic average of 0.037 mD).

From a physical sciences viewpoint the conclusion from research and modelling indicates that there is no significant physical impact on sealing barriers from the injection pressure, provided the recommended upper injection pressures are not exceeded. The recommended injection pressures are detailed in Table 7-1 and in the general Table from Chapter 1, Table 1-1. This is further discussed in this chapter and also the risk assessment in Chapter 12 and to a lesser extent Chapter 11 and 13.

Figure 7.1 is a 3D model of the Moonie Oil Field, Precipice "Oily Water Leg" (in bright green) sitting over the Precipice Formation water leg (in blue). It illustrates the dome-like anticline structure in which oil, solution gas and water are trapped. It also illustrates the location of the existing Moonie Oil Field wells and shows how the Precipice Sandstone drapes over the pre-Permian structure.

Figure 7.1 The 3D Moonie Anticline



Reservoir static and dynamic models have been created (by Bridgeport and independently by UQ) based on pressure data collected downhole from existing wells over the past 50 years. These models forecast future oil reservoir pressure changes over time and movement of CO_2 within the oil reservoir under various injection regimes.

The models forecast a potential minor local increase of pressure in the water column within 0.5 km of <0.2 m in head, which will be observable from the production-monitoring boreholes surrounding the injection well M27. At the planned injection rate of up to 120,000 tonnes of CO_2 per annum, a relatively small injection volume, the model predicts no change in the water column height of local boreholes within the immediate Moonie Oil Field precinct. Modelling shows that CO_2 injection activities will have no impact on local landholders.

It has been documented that there is substantially more impact from CSG operations, which are active in the shallower formations of the greater regional area. The Condamine Irrigation Alliance reports borehole water column height drops within their boreholes averaging >80 m due to the combination of several factors, including CSG operations and drought. These factors need to be taken into consideration when considering potential impacts to local boreholes.

Due to the small injection volume any thermal effect will occur in the immediate injection zone and will be localised within the upper oily water leg within the anticline, having no effect outside the anticline and not impact the greater Precipice main water leg or the reservoir seal. (see section 7.4).

7.1 Introduction

This initial project proposes injecting $scCO_2$ into the Precipice “oily water-leg” for the purpose of increasing the ultimate oil recovery from the Moonie oilfield. The potential environmental impacts of injecting CO_2 have been carefully considered within the project area, particularly in relation to the Precipice and other formations (detailed below).

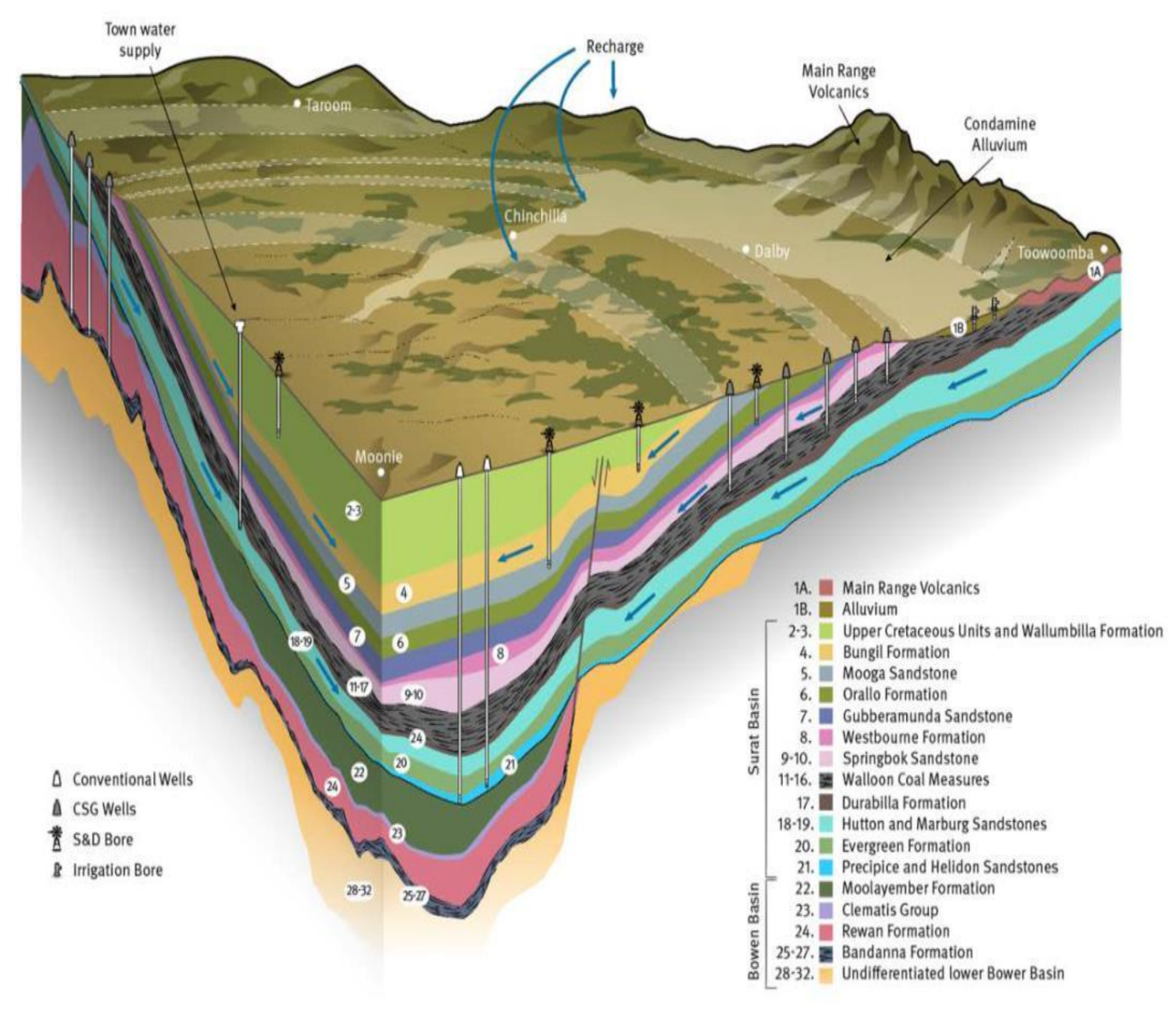
The PL1 Moonie Oil Field is located within the southwestern area of the Surat Cumulative Management Area (CMA) where the Queensland Government Office of Groundwater Impact Assessment (OGIA) has developed a large-scale groundwater hydrostatic model from the collective underground water impact studies submitted from companies and organisations located within this region. The OGIA model predicts and reports on gross aquifer pressure changes across a large area.

From the surface, the geological units present at Moonie and their hydro stratigraphic classification by OGIA (2016) are:

- Springbok Sandstone: a major aquifer,
- Walloon Coal Measures: productive coal seams,
- Eurombah Formation: aquitard,
- Hutton Sandstone: major aquifer,
- Evergreen Formation: aquitard,
- Precipice Sandstone: major aquifer, and
- Moolayember Formation: aquitard/minor aquifer.

Figure 7-2 represents a hydro stratigraphic model of the Surat Basin groundwater illustrating the layered sequence of aquifers (sandstone reservoirs) and aquitards (shaly silty seals) with the surface location of Moonie indicated in the lower left-hand corner (OGIA 2016)

Figure 7-2, A 3D Hydro-stratigraphic model of the Surat Basin (OGIA 2016)



7.1.1 Local well borehole water column heights.

The existing production wells in the Moonie Oil Field are sub-artesian, meaning that the oil and water cannot flow naturally to surface due to lack of reservoir pressure, so artificial lift (pumping) is utilised. The original oil reservoir pressure within the Moonie field has diminished slightly over the six decades of production. At the proposed CO_2 injection volume and rates, the model predicts that the oil reservoir pressure in the field will increase, but insufficiently to reach original reservoir pressure. However, once production ceases then the model predicts the oil reservoir pressure will over time approach the original reservoir pressure.

The Moonie Oil Field anticlinal structure has trapped the existing gases (including existing 5% CO_2), oil and water within the structure for an estimated 60 Ma proving the efficacy of the seals.
The Hydrogeological studies collectively completed by Bridgeport and UQ include:

- the regional and local geological structure and formation properties (see Chapter 6),
- the groundwater systems inside the oil reservoir and in the layers above and below the oil reservoir,
- the chemistry and water pressure gradients of the groundwater (see Chapter 8), and
- the potential impact on the groundwater receiving environment (see Chapter 13).

7.2 "Precipice Oily Water Leg" Permeability and Hydraulic Conductivity

Average horizontal permeability of the upper Precipice oily water leg is approximately 580 mD (millidarcy) and vertical permeability 127 mD with an average porosity of 16.8%. This is based on core analysis (permeability tests conducted by University of Queensland), production well testing and drill stem tests of the discovery wells and is further discussed in Chapter 9 Predictive Reservoir Models and Petrophysics.

The Evergreen Formation and Moolayember Formation (see Figure 7-2), which overlie and underlie the Precipice Sandstone respectively, are typically one to two orders of magnitude lower permeability than the Precipice (OGIA 2016) and include impermeable aquitard layers. Digital core analysis and mercury injection capillary pressure data for the Evergreen Formation (as reported in Chapter 9, Petrophysics) support this conclusion and demonstrate that the Evergreen has a lower permeability in the Moonie field.

7.3 Injection Pressures

Fracture pressures, thermal effects, and fault reactivation pressures as constraints to maximum bottomhole injection pressures and minimum temperature have been examined. Some conclusions are:

- Injection pressures (flowing bottom hole pressures) will need to be constrained (reduced) to remain below a thermally adjusted estimate of the fracture gradient (see specification in Table 7-1 below),
- Reservoir fracture pressure can be reduced due to thermal effects (cooling) from CO_2 injection, particularly at high injection rates. This is factored into the calculation of the maximum allowable fracture pressure detailed below on the assumption such a condition is realised,
- The recommended pressures are detailed in Table 7-1 below as estimated by UQ,

Table 7-1, Recommended Bottom Hole Pressures (BHPs)

Item	Bottom Hole Pressures	
	(kPa)	(psi)
Maximum Allowable Injection Pressure (thermally adjusted - 14.5% from the fracture pressure of the overlying seal)	39,388	5,712
Casing Yield Pressure * depends on type and design,	26,500	3,844
Miscibility * depends on temperature and pressure of $scCO_2$	>11,380	>1,605
Estimated Injection pressure range, depends on temperature, mass, density	11,380 to 39,388 Depending on yield pressures	1,605 to 5,712 Depending on yield pressures

7.3.1 Co2 Miscibility Effect

The CO_2 miscibility effect is highly dependent on a range of factors such as temperature, pressure, pore throat size and geochemistry of the receiving formation water. The recommended bottomhole pressure conditions listed above have been modelled and the injection pressure will be substantially below the temperature adjusted fracture pressure of the receiving formation and overlying seal. Injection pressure is subject to trial, but the upper injection pressure will be limited b the thermally adjusted pressure, which is significantly lower than the formation fracture initiation pressure estimated by UQ.

7.3.2 Fault Slip Analysis

Fault slip analysis using Monte Carlo simulation (to account for uncertainties in stresses and fault orientations/geometries in the deeper part of the Surat Basin) suggests the pressure at which fault slip would occur (P90 = 53,150 kPa, mean = 57,250 kPa) is substantially higher than the BHP limit of any injection well, as determined by other operational constrains. It is thus not a significant risk to this injection project

7.3.3 Subsurface pressure constraints on injection

Injecting $scCO_2$ (or any other fluid) will increase the pressure in the immediate injection zone. This increase in pressure, will be largest around the perforated interval of the injection well and decreases with distance (both horizontal and vertical) away from the well (this is predicted by the model in Chapter 9). A pressure threshold at surface will limit the injection pressure of the $scCO_2$. to maintain safe operations.

7.3.4 Fracture pressure

If the pressure at the injection well reaches a certain level it is possible to mechanically fracture the rock. The pressure at which this occurs is the fracture pressure of the formation. Exceeding the fracture pressure will cause fractures to propagate into or through the receiving formation and/or the overlying sealing formation. Therefore, the bottom hole pressure (BHP) of the injection well should not be allowed to increase above the fracture pressure. A safety margin should be employed to ensure this does not occur, with BHP limited to 90% of the fracture pressure as the maximum limit of injection wells, a value used in Canadian EOR operations (Bachu and Gunter 2005).

An additional consideration when assessing the actual fracture pressure as a limit for the injection well BHP, is a further reduction in fracture pressure due to possible thermal effects of injecting relatively cool scCO_2 into a relatively warm reservoir.

Vilarrasa et al (2015) determined that the thermal effects were only evident in the injection zone and “lowest tens of metres” of caprock in their injection models in Salah, Algeria. This suggests if the caprock is thick enough, the thermal effects of CO_2 injection are unlikely to jeopardize the top seal capacity.

The Precipice “Blocky Sandstone Reservoir” in the Surat Basin is overlain by a Transition Zone, which is typically 20-80m thick. The Transition Zone is geologically complicated with significantly lower permeability than the underlying Blocky Sandstone Reservoir, however, it is not being considered as the main seal for containment of scCO_2. Simple UQ-SDAAP project models of notional scCO_2 injection in the including thermal effects showed that the cooling effect of the scCO_2 is focused on the injection well completion area or zone.

7.4 Thermal effected injection zone

UQ constructed a simulation model of a well completion at the base of the Blocky Sandstone Reservoir. In the model, injected scCO_2 was 30°C cooler than the initial reservoir temperature and it was estimated that the lowest 5m of the (geologic) Transition Zone was cooled by 20°C after 30 years of injection at a rate 10 times greater than this initial project injection rate (Rodger et al. 2019c). This initial project considers a much smaller injection volume and period, significantly diminishing the potential effect described by Rodgers above.

While much larger than the proposed initial project, the full-scale Moonie injection model is similar in scale to simulations by Vilarrasa et al (2015) which suggests that while the lower part of the geologic Transition Zone will experience some cooling, there will be no thermal effect propagating up to the overlying Ultimate Seal. Nonetheless, 90% of the ‘thermally adjusted’ fracture pressure will serve as a bottomhole pressure limit for notional injection wells.
With improved understanding of the geomechanics (i.e., the stress profile) of the Transition Zone, it may be possible to safely inject above the fracture pressure of the reservoir. These properties will be examined during this initial injection project.

7.5 Slip Tendency

Since pressure during injection diffuses radially, and rapidly decreases with distance from the injection well, potential injection sites should be located away from significantly faulted areas to eliminate the risk of scCO_2 leakage through the MG fault. Reservoir modelling has shown that the CO_2 does not approach the MG fault over the initial 8-year project and that the original reservoir pressure will not be reached. Given the small injection volume and the proposed operational BHP limits, the risk of fault slip is remote to nil.

7.6 Fault Reactivation Pressure

As well as assessing fracture pressure as a limit to well BHP, fault reactivation pressure was assessed probabilistically by UQ using a Monte-Carlo approach and Mohr Coulomb failure analysis. It suggested that the pressure at which fault slip would occur is likely to be significantly higher than the BHP limit (avoiding inducing fractures in the blocky sandstone reservoir) of any injection well. Injection wells need to be located away from any faulted areas (to mitigate the risk of CO_2 leakage through faults). Pressure quickly decreases with distance from the injection well due to radial diffusion of the relatively minute volume in an extremely large container and it is extremely unlikely that fault slip would occur due to injection operations.

7.6.1 Conclusions

If 90% of the mid-case fracture pressure is used as the operating maximum bottomhole pressure (BHP) for injection wells, the BHP limit would be 39,750 kPa at 2,300m. If injection wellhead pressure (WHP) is controlled at surface, then this BHP limit would not be reached during the scCO_2 injection project.

7.7 Groundwater Chemistry

The groundwater chemistry of the oil reservoir is unique and naturally contains crude oil, other associated chemical compounds (e.g., BTEX) and formation water. These characteristics are entirely different to the Evergreen Aquifer and the Precipice Main Water Leg and is further discussed in the section on Groundwater Geochemistry (see Chapter 8).

7.7.1 Impact of CO_2 on water quality and seals

Core from the Moonie field was analysed by UQSDAAP for porosity and mineral content to build geochemical models and predict chemical reactions between the formation water of injected scCO_2. The current base line formation water quality is listed in Chapter 2, Table 2-5: Average Moonie Water Quality Readings, this data is gathered quarterly.

The Precipice sandstone in the Moonie Oil Field has been found to have different mineral and pore characteristics than studied well core samples in the northern regions of the Surat Basin.

The analysis of the scCO_2-formation water-rock minerals behaviour model indicates a general formation water pH decrease can be expected in the Moonie Precipice Sandstone ('58 sands') buffered by higher dissolved bicarbonate content (than in the northern Surat Basin) and by minor mineral dissolution to a pH of 4.8-5.3 over time.

In the laboratory experiments and in modelling by UQ, the addition of sc$CO_{2,}$ resulted in the water pH being buffered to 5-5.6. (Rodgers etal 2019) Ankerite and minor kaolinite was precipitated in cleaner sandstones, and smectite in clay-rich sandstones and shales samples of the Moonie core. Precipitation of smectite may maintain or improve sealing capacities of clay rich seals and may adsorb CO_2.

The formation water in the Precipice "58-10" sands is carbonate rich solute which has an inherently high buffering capacity. The reaction of these formation waters with carbonic acid (when CO_2 forms an acid in the presence of water) and the 3 chemical methods of chemical entrapment are discussed in Chapter 8 Groundwater Chemistry. The predicted alteration of carbonates and feldspar is consistent with observations from experiments using relative permeability reactions performed as part of the UQSDAAP & CTSCo projects. Precipitation of kaolinite, ankerite, smectite has been observed where there has been natural CO_2 alteration.

Evidence of previous natural thermogenetic CO_2 and hydrothermal fluid alteration, fractured quartz grains, and fracture fills has been observed to occur with mineral trapping as carbonates in core samples throughout the Surat Basin. Similar reactions will occur with the mild acid produced from the CO_2 and water as explained in Chapter 8.

An analysis of the Precipice oily water leg indicates the water within the oil reservoir is:

- of very low surface beneficial water quality, due to the oily water characteristics (Table 2-5), and other factors discussed below. When it arrives at the surface it is directed to evaporation dams and BEL has no beneficial reuse arrangements with the landowners nearby,
- being of a “disturbed” nature brought about by constant pumping over several decades, and
- without treatment is unfit for any commercial-beneficial use.

Being in an anticlinal structure, the Precipice oily water leg is not directly connected to the surface or sub-surface hydrological systems (aquifers) used by landowners in the area.

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This Chapter discusses the modelling of chemical reactions between the injected CO_2 and groundwater over time. It details the water of the target “Precipice oily water leg” found within the “Precipice Formation” and the surrounding water legs at an injection depth greater than 1.5km. The probable impact on groundwater quality has been modelled over time and risk assessed, as discussed in Chapter 12 Assessment of Impact Groundwater, and Chapter 13, Impact on the Receiving Environment.

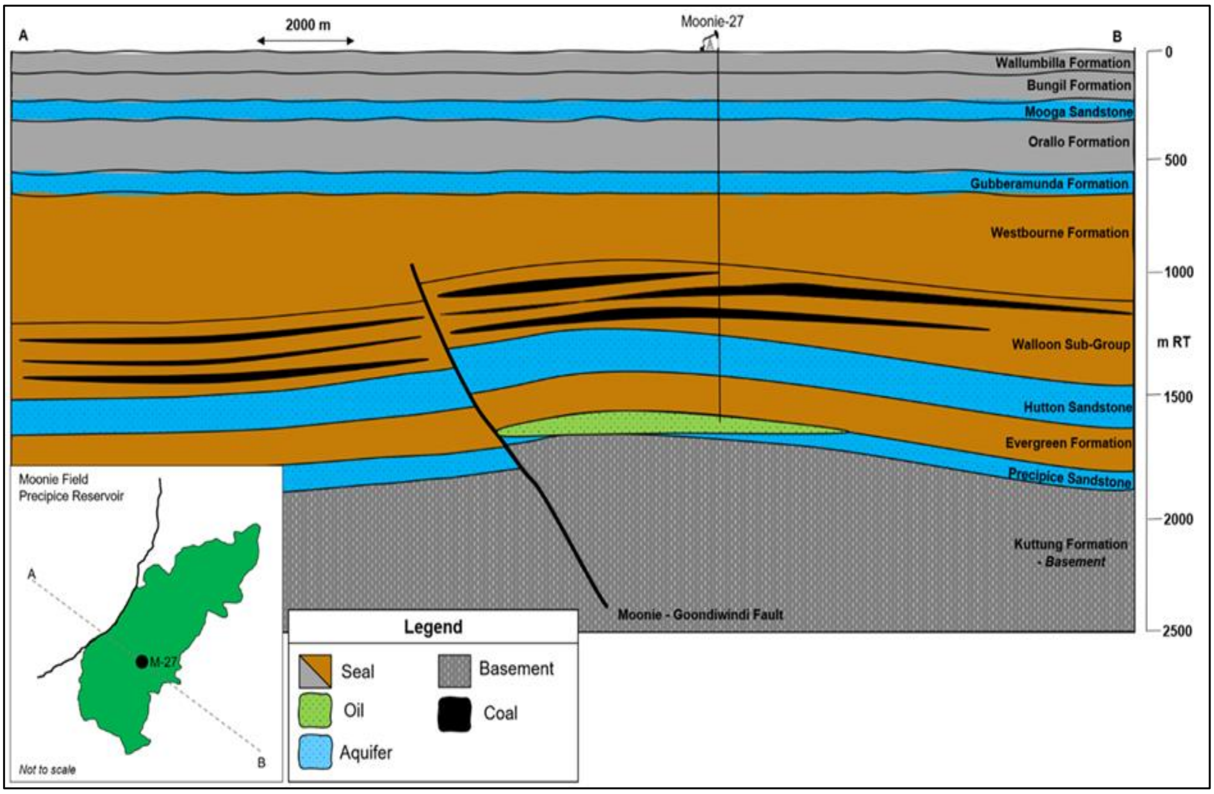
The key points for this chapter are:

- There will be no significant deterioration or impact on the quality of the existing groundwater within the “Precipice oily water leg” as a result of CO_2 injection.

- An impermeable top seal separates the Precipice Sandstone from the overlying Evergreen Member. The seal has trapped gas, oil and water for approximately 9O Ma. It has also isolated the water of the Precipice Sandstone reservoirs from those of the overlying Evergreen Member with each having water of a distinct isotopic signature, i.e., each being unique.

- There are two distinct zones and water bodies within the Precipice Formation (see Figure 8-1, overpage),
    - the upper “Precipice oily water leg” – water once underlying the trapped Moonie oil reservoired in sands of the Precipice Sandstone. Small quantities of oil left in the Precipice sands post-production, has mixed with the water. This ‘Precipice oily water leg’ is retained within the Moonie structural trap (anticline) and is above and separate to the main “Precipice water leg”, (see Figure 8-1, overpage),
    - Overlying the Precipice Sandstone is the Evergreen water leg, separated from the “Precipice oily water leg” by a 20-80m thick impermeable layer of the Lower Evergreen Member (Figure 8-1).

Figure 8-1 The Precipice "Oily water leg" (light green) situated in the Moonie Anticline



- The chemistry of the lower main "Precipice water leg" is distinctly different from the upper "Precipice oily water leg". The "oily water leg "has a high carbonate content, gases (including CO_2), oil, oil derivatives (with a geothermic origin as against a biogenic origin) and water. The 'Precipice water leg' remains relatively pristine.

- The "oily water leg" has been produced for decades and what remains is classified as "disturbed" from its original condition, i.e., contaminated by oil and production/completion fluids,
    - The current untreated water has been assessed by DES applying S.41 of the EPAct Regulations and is classified as a "waste". It would be identified as polluted or contaminated by oil and related chemicals, and therefore excluded from protection by the EPAct 2019.

- The extracted groundwater quality is poor to unusable without treatment. No public boreholes to access water at this depth or stratigraphic unit exist within the immediate area.

- While this assessment of water quality is normal for an oil field reservoir; it is not normal groundwater envisaged by the EPAct 2019 for protection.

- This initial injection project will not significantly alter or adversely impact the oil reservoir baseline conditions.

- The CO_2 will react with water on contact forming carbolic acid, which in turn react with elements present in the reservoir (other than quartz and chert comprising the bulk of the formation). The resultant molecules or compounds are chemically trapped in the "oily water leg" through solubility, ionic and mineral entrapment reactions (Section 8.9). Of the molecules not trapped and remaining in solution, initially the drawn down pressure applied by the PM wells by the artificial pumping equipment will cause a flow of fluids in the oily water leg and any untrapped molecules (but those remaining in solution) will move to the production wells and then to the surface. When pumping ceases, the altered molecules remain entrapped in the anticline.

- The carbolic acid will not alter the target formation as it is comprised of Quartz and Chert which is unreactive to acid,

- Theoretically, some of the molecules of CO_2 mixing with water have a slightly higher density and will initially move downward under gravity. However, the movement is limited by permeability of the rock formation in the oily water leg, at a depth greater than 1.5km, and also by the fact that the $CO_2 + H_2O$ reaction is a two-way reaction. As the heavier CO_2/water molecule meets more water and/ or the pressure reduces or temperature increases, the reaction reverses and the CO_2 dissociate from the water and returns to a gaseous form. It will then migrate to the top of the anticlinal trap

- SOx and NOx molecules (at a delivered concentration of 20ppm and 33ppm respectively from the Milmerran CO_2 delivery specification, in Chapter 10 Assessment of Impact Air) are also trapped in the anticline and the 3 chemical entrapment mechanisms are discussed below,

- Negligible amounts of hydrogen sulphide (H_2S at 15ppm) is present in the received CO_2 fluid stream and injected (see the delivered CO_2 specification in Chapter 10 Assessment of Impact Air). Downhole it reacts with water to form a weak sulphuric acid which in turn reacts with the carbonates in solution, including the carbonic acid. The sulphuric acid is neutralised and entrapped. Of the elements not entrapped in this process (if any), while the injection program is continuing, the remaining H_2S in solution will be produced at the surface separator unit. However, the amount of H_2S is estimated to be so minute as to be immeasurable. The gas from the Separator will be fed to and burnt in the generator. In this process, H_2S is burnt and changes to sulphur and water.

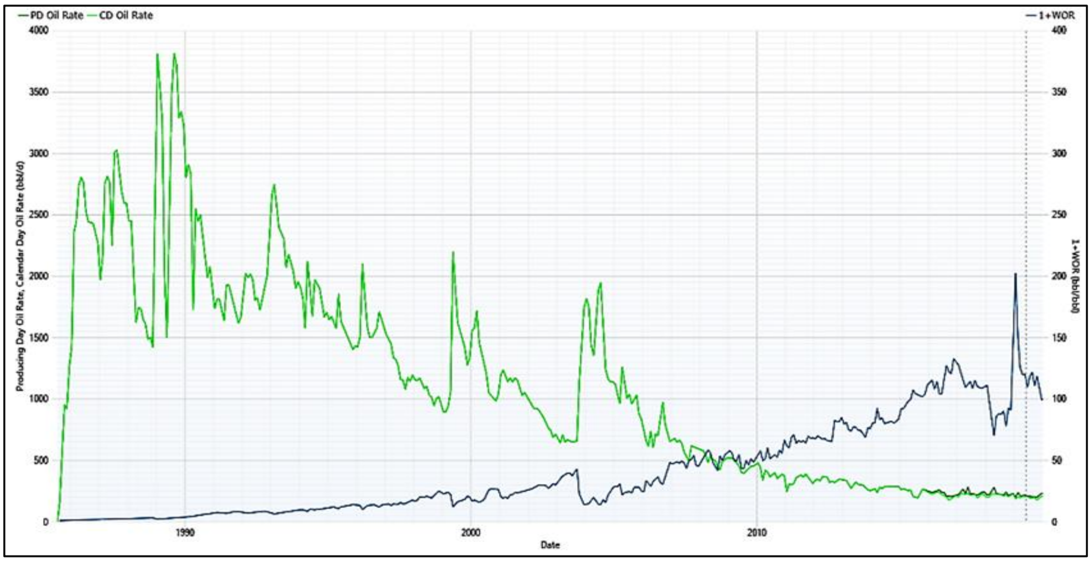
This chapter discusses:

- The stratigraphy potentially affected by the injection of CO_2,
- The chemical processes predicted in the injection zone at the perforations (validated by laboratory tests),
- The associated chemical reactions of various products in the reservoir (CO2 and any associated gas products from the CTSCo plant),
- The nature and time scale of any change; and
- The stability of the CO_2 flood once injected.

8.1 Background

Currently the percentage of oily water being pumped to the surface is declining and water is increasing. A typical production profile of the latter years of a depleted oil field is illustrated in Figure 8-2 below. The economic life at current production of PL1 is predicted to be extended by 10-12 years through tertiary recovery using enhanced oil recovery, as discussed in Chapter 18.

Figure 8-2 A plot of Moonie Oil versus Water production.



8.1.1 Water Quality

The Moonie Oil Field “oily water leg” has been producing for decades. The remaining fluid in the “Precipice upper water leg” is classified as “disturbed” from its original condition. A mineralogy and groundwater quality profile has been developed, tracked, and reported to Government by field operators for over 50 years. Under the current EPAct and Regulations and Schedules, the quality of the Moonie “oily water leg” without treatment would be classified under the legislation as being a waste and toxic. The water is assessed under the ANZACC water guidelines (2000) as being unfit for human or stock consumption. While this assessment of water quality is normal for an oil field reservoir, it is not normal groundwater envisaged for protection by the EPAct 2019. Depending on its quality produced water at Moonie cannot be directly used at surface without treatment.

No public boreholes to the depth of the Moonie “oily water leg” exist in the immediate region. Local landholders prefer to access cleaner water found at shallower depths.

The initial injection project will not significantly alter or adversely impact the oil reservoir baseline conditions. Reservoir modelling by the University of Queensland (UQ) indicates that, as a result of CO_2 injection, the pH contained within the “oily water leg” contained within the Moonie anticline will move towards a neutral state and over the long term will revert to original reservoir conditions. This factor alone could be perceived as a positive impact of CO_2 injection.

8.1.2 No connection with surface Waters.

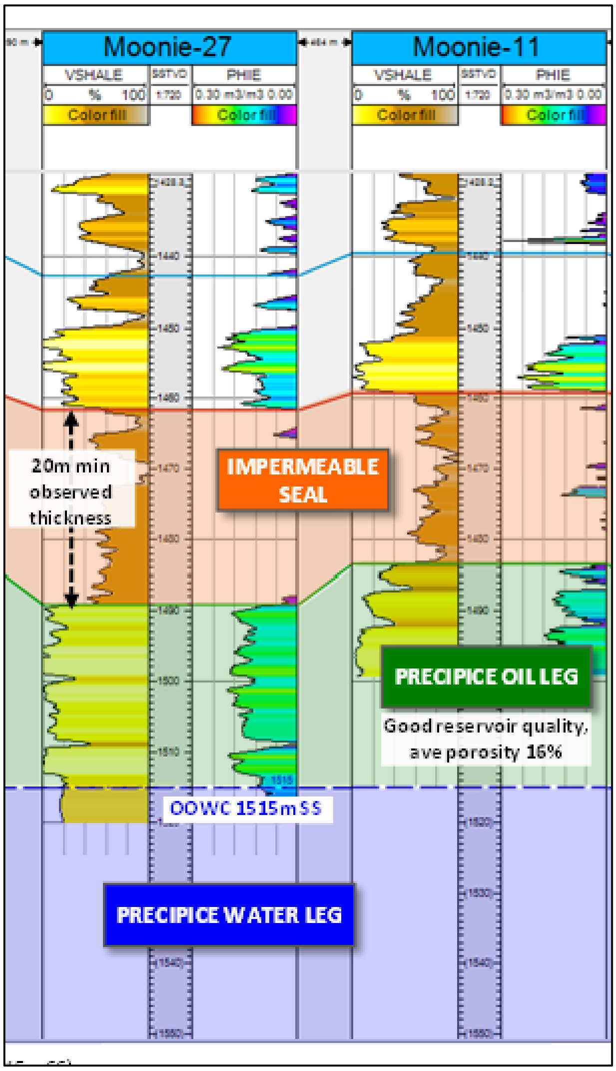
From the UQ study, there is no evidence of hydro-chemical connectivity between the Precipice Sandstone and surface water (river drainage).

8.2 Existing Groundwater Chemistry Characteristics

The formation water chemistry of the Moonie oil reservoir has a different chemical composition than the water in shallower aquifers at less than 300m accessed by the majority of Landholders and contains oil, long chained hydrocarbons and other linked organic chemicals (BTEX). It has also been “produced” for more than 5 decades and as such is classified as being “disturbed” from its original condition. This is unlike the upper and lower water bodies (the Evergreen and the lower Precipice Main Water Leg) which are still in ‘virgin condition’ Table 8-1).

The isotopic signature of the “Precipice main water leg” is completely distinct from the water in the overlying Evergreen aquifer, confirmed by isotopic water analysis completed by University of Queensland (UQ). This difference in water chemistry and the entrapment of oil in the Precipice Sandstone proves that there is an impermeable seal between the Precipice Sandstone units and the overlying Evergreen Member isolating the sands of the two members of the Evergreen Formation. (see Figure 8-3, a cross section highlighting basal Evergreen Member shale separating sealing Precipice SS.). Testifying to the strength of the impermeable Precipice topseal, which has trapped gas and oil for approximately 9O Ma years.

Figure 8-3 Cross section highlighting the basal shale separating the sealing Precipice SS



8.2.1 Upper Precipice Seals

The upper Precipice Sandstone seal is discussed in Chapter 5 Geology and Geomorphology. The seal is 20 -80m thick, depending on location. The contact between the Precipice Sandstone and the overlying Evergreen Member seal is transitional in nature.

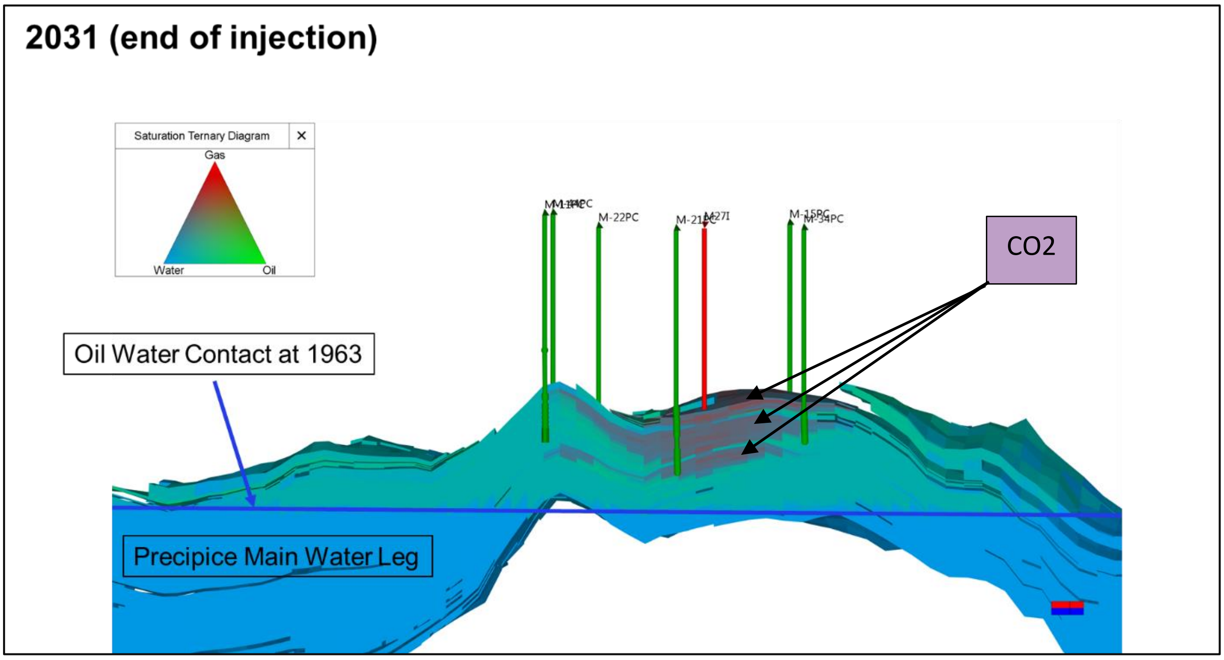
The impermeable nature of the Precipice Sandstone seal means that injected supercritical $scCO_2$ (which is less dense than water or oil) will migrate upward within the Moonie structure until it reaches the base of the impermeable seal (Bachu, 2000). When the front face of the injected $scCO_2$ flood front contacts water it forms a mild carbonic acid as discussed below. As the front reaches the contact surface of the transition zone before the impermeable seals, the mild carbonic acid will form a self-sealing carbonate-based mineralisation, which prevents further penetration of the transition zone and the seals.

8.2.2 The Main Precipice Water Leg

Approximately 60,000,000 tonnes of oily water have been produced from the Precipice Sandstone to date. This has been a by-product of decades of oil production from this interval (since 1963). The Bridgeport Energy dynamic model predicts with an initial injection volume of 120,000 tonnes/year over 8 years into the Precipice 'oily water leg', the CO_2 flood front will not reach the oil-water contact of 1963 (Figure 8-2). A total of 960,000 tonnes of CO_2 will be injected over the modelled 8 years, 20% of the injection volume is discharged at surface leaving 768,000 tonnes sequestered. The 768,000 tonnes is significantly less than the 60 M tonnes extracted being only 1.3% of the extracted volume.

Figure 8-4 illustrates the predicted position of the oily water interface and the injected volume of CO_2 at the cessation of pumping in 2031.

Figure 8-4, a 3D cross-section model of the Moonie Oil Field Injection zone at completion of injection in 2031



The remaining CO_2 gas (coloured purple above in Figure 8-2) is illustrated as residing at the top of the structure. This volume is small enough that there is no potential for the buoyant $scCO_2$ to penetrate the main Precipice main water leg during the injection program, as the injected fluids will only occupy a small percentage of the potential extracted volume within the oil field.

8.3 The Associated CO_2 Chemical Reactions

The addition of liquid CO_2 and minute amounts of SO_x and NO_x entrained in the CO_2 stream can partially dissolve in water to form the hydronium ion (H_3O^+). The latter has a moderate affect in lowering the pH where the $scCO_2$ flood front reacts with formation water.

The various entrapment reactions are illustrated in Table 8-1 below.

Table 8-1, Table of Chemical Reactions

Carbonate Reactions - dissolution and dissociation of CO_2 in water	1. CO_2<-> CO_2 (aq) 2. CO_2 (aq) + H_2O <> H_2CO_3 3. H_2CO_3<-> H^+ + HCO_3^-
SOx Reactions	4. SO2 + H2O -> H2SO3 5. H2SO3 + H2O > 4H+ + $SO4^{2-}$
NOx Reactions	6. 3NO2 + H2O >2 HNO3 + NO(g) 7. HNO3→ H+ + NO3-

Modelling predicts that, over time, the existing slightly alkaline pH within the “oily water leg” will change to a pH range of 5.0 to 5.5. The model predicts that the altered pH will return to the original reservoir pH level over time. In contact with minerals, carbonates and clay, the CO_2^- ions react and that reaction buffers the pH, precipitating self-sealing minerals in the immediate area. The reaction only occurs on exposure to the minerals and proceeds to completion until spent.

At cessation of pumping there will be no fluid movement within the anticline.

The primary mineral of the Precipice Sandstone at Moonie Field is quartz at approximately 80% (Pearce et al, 2019), followed by feldspar and chert. These primary components are all inert and not reactive to acid. The rock integrity/structure is therefore not predicted to be degraded by changes in the pH of the formation water. Otto (2998) made conclusions based on entirely different geological formations, not at depth (1.5km to 2.2km) and modelled on an entirely different volume of injected CO_2.

However, due to the geological anticline formation, carbonates in solution have accumulated in the Moonie Anticline for 90 Ma, as distinct from the main Precipice water leg. Because of the relatively strong water drive in the main “Precipice water leg”, there is a distinct difference to the minerology of the upper “Precipice oily water leg” which has less flow and is trapped in the anticline.

At the local exposure front with surrounding carbonates and other minerals in solution, the carbonic ions react with the carbonate, clay, and minerals (see discussion in Chapter 6) to precipitate self-sealing carbonates and minerals. The reaction only occurs on exposure to the minerals and continues as long as liquid CO_2 is in contact with the minerals.

When injection ceases and the production monitoring wells are shut in, all the fluids in the reservoir become static and there will be no fluid movement within the anticline.

8.4 CO_2 containment

The geochemical reactions are controlled by several factors and combinations of scCO_2, water, rock characteristics, temperature, pressure, pH, and minerology of the receiving environment. UQ has modelled this chemistry over time (up to 1,000 years). The modelling indicates the injected CO_2 does not stay in the scCO_2 phase but converts to the normal CO_2 phase and remains trapped within the anticline in the Precipice “oily water leg”.

8.5 Migration of CO_2 and Related Ions

At reservoir conditions, the scCO_2 is less dense than both water and oil, despite the relative molecular weight and will naturally migrate to the top of the Moonie anticline. The injected CO_2 in this initial project will only fill <15% of the volume available in the uppermost part of the structure. Once pumping stops the artificial fluid drive stops and so does the movement of the CO_2 within the unit. At this stage the scCO_2 remains trapped in the upper sandstone of the anticline.

During migration, the CO_2 will react with minerals and fluids. Certain reactions will create “heavier” molecules that under normal circumstances, will migrate slowly downwards until they come into contact with formation water and disassociate. If some heavier molecules are not trapped once they come into contact with water, they are disassociated and return upwards in the anticline. The sheer volume of water and the water drive in the lower main Precipice water leg would move to dilute and dissipate any further effect.

8.6 Chemical Reactions of Hydrogen Sulphide with Water and Air

Hydrogen sulphide is present in the delivered CO_2 at a concentration of 15 ppm. Hydrogen sulphide gas reacts with oxygen gas to yield sulphur dioxide gas and water. This could occur on uplift and at the separator, however the expected volume is expected to be negligible. For completeness, the chemical reaction with Air is:

Skeleton equation: $H_2S(g) + O^2(g) \rightarrow SO^2(g) + H_2O(l)$,

Balanced equation: $2H_2S(g) + 3O^2(g) \rightarrow 2SO^2(g) + 2H_2O(l)$.

8.6.1 Production of Sulphuric Acid from H_2S & H_2O

Hydrogen sulphide (H_2S), which is slightly soluble in water, reacts with water to form a weak sulphuric acid. As a weak acid, it dissociates initially into the hydrosulphide ion, HS^- (pKa=6.9), and then the Sulphide ion, S^{2-} (pKa=11.96). The presence of the hydronium ion, H_3O^+ is also present.

The reaction is detailed below and can cause corrosion with metal in high concentrations,

$H_2S + H_2O$ $^-$--> $HS^- + H3O^+ \cdot HS^- + H_2O$ $^-$--> $S^{--\ +}$

However, H_2S is neutralised by the presence of sodium, calcium bicarbonate and other carbonates (e.g., magnesium bicarbonate), all of which are present in the “Oily Water Leg”. Further, the H_2S will be trapped via the two chemical entrapment mechanisms discussed below in Sections 8.7.3 (Ionic Trapping) and 8.7.4 (Mineral Trapping). The H_2S which is not trapped chemically (if any) will be part of the fluid stream being brought to the surface by pumping. The H_2S present in the surface separator will be directed to the generators where the residual H_2S will be burned. In this burning process, the H_2S is converted to water and sulphur.

OSHA established an atmospheric eight-hour H_2S permissible exposure limit-time weighted average (PEL-TWA) of 10 ppm and a 15-minute short-term exposure limit (PEL-STEL) of 15 ppm for exposed workers. NIOSH sets the recommended exposure limit to 10 ppm. As the hydrogen sulphide will be contained within the liquid phase, there is no direct risk to workers. If the H_2S in the liquid phase were to change phase to a gas, then the liberation of the H_2S would be in the atmosphere. The above workplace safety threshold will be adopted. The presence of H_2S as a gas is already routinely assessed in the Moonie Oil Field and monitoring apparatus are on hand. Notwithstanding, this assessment will be extended to the separator and generator and become a routine monitoring program at the facility.

8.7 Fate of Oxygen, Iron, Manganese and Heavy Metals

Given the small amount of CO_2 being injected, modelling predicts that the pH level will change from slightly alkaline to neutral where contact with minerals, carbonates and clay is made. In this process, the suite of ions associated with iron, manganese and heavy metals are held in solution, instead of precipitating out of increasingly acidic solutions. Furthermore, Otto (1998) correctly identifies that oxygen is usually depleted in the oily water leg, as is the case at Moonie.

8.8 The fate of NOx & SOx.

A relatively small concentration of NO_2 and SO_2 compounds will be present in the predominantly liquid CO_2 delivered to the field. The scCO_2 flood front is controlled by migration towards the crest of the structure and the ongoing removal of the "oily water leg" fluids by pressure reduction at the five PM wells. In this initial injection project, eighty percent of the delivered scCO_2 is sequestered in the depleted formation by a combination of chemical entrapment and physical forces (density - buoyancy). Similarly, minor SO_2, and NO_2 fractions are also entrapped via the same reactions discussed above. (Table 8.2)

8.9 Geochemical Trapping Mechanisms

The chemical containment of CO_2 in the reservoir occurs in three distinct ways (Kriste et al., 2004):

1. Solubility trapping, where CO_2 dissolves or partly dissolves into the receiving environment (water),
2. Ionic Trapping, where the ionic species HCO_3^- and CO_3^{2-} are formed from dissolving CO_2; and
3. Mineral Trapping, where the dissolving CO_2 forms sealing carbonate and precipitates as it reacts with minerals, colloidal clays and carbonates particularly at the Precipice seal interface.

8.9.1 Solubility Trapping

The $scCO_2$ partially dissolves on contact with water and is held within the aqueous phase. During this process there is a phase change from $scCO_2$ to CO_2.

8.9.2 Ionic Trapping

The $scCO_2$ partially dissolves in water, producing carbolic ions (Table 8-1). These ions then react with the carbonated solution, in essence trapping the ions within the new carbonate products formed.

8.9.3 Mineral Trapping

As the $scCO_2$ comes into contact with clay-based or carbonate minerals, the resulting reaction produces carbonate-based elements which entrap the CO_2 and related ions.

8.10 Supercritical $scCO_2$ and Oil Miscibility

Based on fluid density, the fluid column within the anticline has segregated into gas, oil and water zones. The miscibility of $scCO_2$ in water produces ions and changes the miscibility of the oil with water, tending to disassociate some of the oil from the oil layer. The rate at which the oil increases its miscibility is dependent on the concentration of oil and related oil fractions, the immediate hydraulic pressure, the temperature, the purity of the immediate elements and the maintenance of the CO_2 in the supercritical state. The rate of change in oil miscibility will be subject to experimentation. Some of the previously held oil fraction becomes more miscible and can flow together with formation water towards the production wells. Some miscible CO_2/water is caught up in this flow with the remainder of the CO_2 being sequestered. For this initial project the model predicts a split of 80% sequestered, to 20% presenting at the production separator. This percentage may increase to 100% sequestered if surface capture and compression is justified on economical/environmental assessment.

8.11 Rate of dissolution of CO2 in Groundwater (Water/Oil mixture)

Change in rate of CO_2 dissolution in water will vary according to a combination of factors including the purity of the CO_2, the maintenance of the supercritical phase, the presence of oil and related products, the presence and state of minerals and elements, temperature, pressure, and water salinity. The final rate of dissolution will be determined by experimentation.

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 9: Predictive Reservoir Models & Petrophysics

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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9.0 Executive Summary

The purpose of this amendment is to validate the initial injection project and demonstrate the potential and the ideal geological trap for long term storage of CO_2. Petrophysical and structural modelling analysis forms the basis to create a reservoir model that predicts the behaviour of injected CO_2, other gases, oil, oil fractions and groundwater within the Moonie anticline Precipice "oily water leg". While the Bridgeport model extends out 50 years the UQ models extend over a period of 1,000 years and indicate the pH returning to the main reservoir conditions along with temperature, pressure, and entrapment of the CO2 within the Moonie oil field anticline.

Petrophysical analysis is used to calibrate and populate the static geological model cells with geologically realistic porosity, permeability, water and oil saturations in the formation, shale contents and other values linked to downhole analysis, using such data as the Moonie Oil Field core plug analysis, well wireline logs and test data. This information is used to analyse trends in the effective porosity and relative permeabilities linked to each stratigraphic zone. This data is then used to produce a dynamic model simulation. Both UQ SDAAP and Bridgeport have created and run different scale models to predict potential behaviour of the CO_2 flood front and pressure changes in response to various injected CO2 volumes and injection pressures of the modelling has shown the potential impacts over time.

Numerous vintages of geological analysis and dynamic reservoir modelling by various operators including Bridgeport and by UQ studies indicate the Moonie Oil Field is a low containment risk and an ideal trap to receive and store CO_2.due to the following factors:

- CO_2 remains in the oil column trap that has been stable for the last 90Ma,
- The target Precipice formation, the "oily water leg" contained within the anticline (the target zone) has sufficient porosity and permeability to allow CO_2 to be injected at the initial intended rate of 120,000 tonnes p.a.,
- The target injection zone has sufficient volume to receive the intended injection volume, the model predicting that only 15% of the available anticline volume will be utilised over the entire injection period of eight years,
- Thermogenic sourced CO_2 and other gases are already evident in the Precipice "oily water leg" in a geological trap that has been stable for the last 90 Ma.
- CO_2 will not be able to migrate upward or downward out of the Precipice anticline due to the intra-formation baffles (low permeability units) and the principal reservoir seal at the top of

the formation or into any regional aquifers without human intervention. The reservoir seal has extremely low permeability (Harfoush et al. 2019a, 2019b, 2019c and Honari et al. 2019a) with core plug measurements of horizontal maximum corrected water permeability ranging from 0.003 to 0.086 mD (arithmetic average of 0.037 mD).

- The operational injected CO_2 pressure does not approach the critical reservoir field pressure limits.
- The regional aquifer or surface systems will be unaffected by the injection of CO_2 into Moonie oil field.
- The injection pressure will never exceed 90% of the fracture pressure and will be controlled by a surface pump governor.
- Injected CO_2 will be at super critical conditions, expanding and compressing like a gas but with the density and acting like a fluid within the geological trap.
- The total volume of CO_2 injected over the proposed 8-year project is 1 million tonnes, being <15% of the existing total available reservoir storage capacity.
- The drawdown pressure created by the PM wells generated by artificial lift cause the oil reservoir fluids to flow towards the producing wells, trapping 80 % of the residual CO_2 within the structure.
- The result is that pressure is transmitted horizontally within the Precipice anticline and dissipates with distance and in the Moonie model, predicts a preferred pathway uptake at the five-surrounding production PMwells.
- Critically, the models validate that pressure is not transmitted vertically through the substantial impermeable ultimate seal.

9.1 Introduction

The digital models from UQ and Bridgeport cannot be included in this amendment due to the size of the models. However, the following discussion is based on the outcomes from running the various models.

Within the Moonie anticline the original reservoir pressure was 17,440 kPa (2,530 psi.). Due to water and oil extraction the average reservoir pressure is currently lower at 16,065 kPa (2,330 psi.). The projected reservoir pressure on injection will be above 16,550 kPa (2,400 psi) and below the reservoir seal fracture pressure and designed to maintain the CO_2 in the supercritical phase within the formation.

9.2 Thermally adjusted Reservoir Seal Fracture Pressure

Based on core tests sampling, the reservoir seal fracture pressure has been calculated by University of Queensland (UQ) at 52,170kPa (>7,566 psi.). Rodger's et all 2019) recommends a safety injection pressure of 90% of the above reservoir seal fracture pressure being 46,953 kPa (6,809 psi). Due to downhole receiving thermal environmental conditions the reservoir fracture pressure is further reduced by 14.5% to 39,388 kPa (5,712 psi).

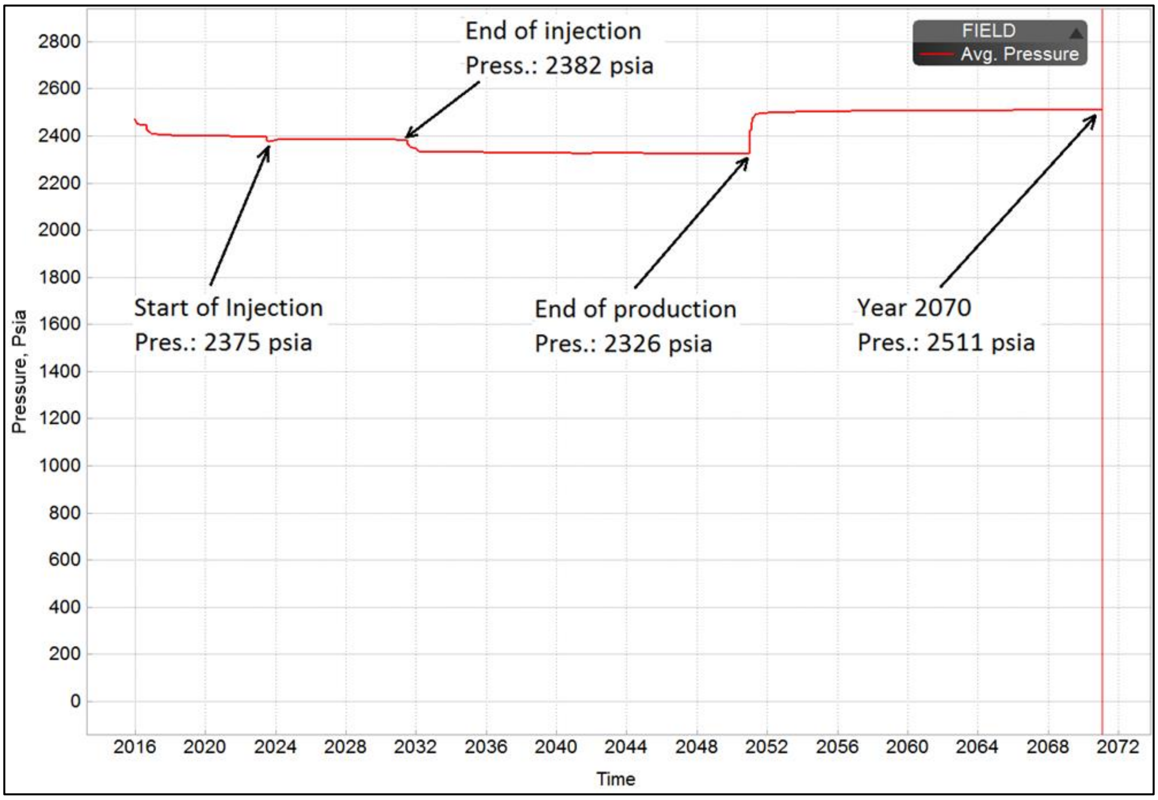
There is a significant safety margin between the planned reservoir injection pressure of >16,550 kPag (2,400 psi) and the thermally adjusted fracture pressure 39,388 kPa (5,712 psi.). Injection pressures at surface will be adjusted between 2,400 psi and 5,712 psi to balance the injection rate of liquid CO_2 with the delivery rate of the CO_2 by road tanker (due to storage limitations).

The greater Precipice main "water leg" sits under the Precipice "oily water leg". The model predicts that the injection process will not change the greater Precipice main "water leg" aquifer pressure.

The following graph Figure 9-1 shows the change in the local pressure of the Precipice oily water leg within the Moonie Anticline out to year 2070. Note the model results demonstrates that original reservoir pressure is not reached by the injection rate of CO_2 during the initial 8-year project and would only be reached in the main sequestration phase after oil production ceases and sequestration commences.

Figure 9-1: Modelled local changes in reservoir pressure during the CO_2 EOR operations is illustrated below.

Figure 9-1, The Plot of the predicted Reservoir oily water leg Pressure over time



9.3 Moonie Model Trap Volumes - Original Oil in Place Calculations

The volumes calculated below are taken from the same reservoir model in the original EA amendment supporting documentation. The model assumes a total 1.0 MMmt of injected CO_2 over 8 years. The results of the Static Model case are detailed in Table 9-1 below,

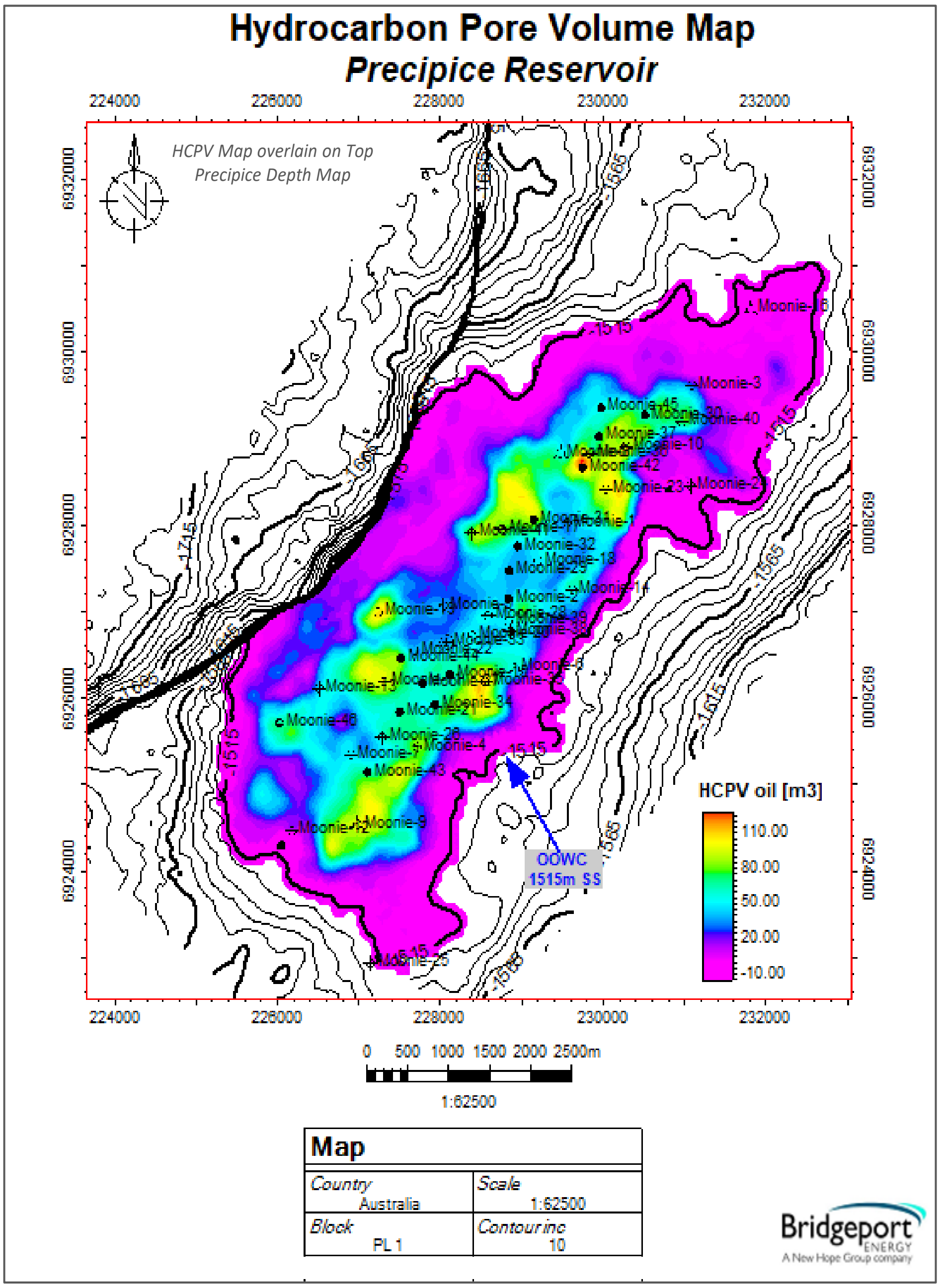
Table 9-1, The Static Model Case

STATIC MODEL CASE *(Base_Case_Moonie_Vols_SGS)*	Bulk volume [MMm3]	Pore volume [MMm3]	HCPV oil [MMm3]
PRECIPICE	545.35	32	11.92

From the model the CO_2 storage potential within the Precipice "oily water leg" reservoir overlying the Precipice "main water leg" is 11.9 MMm^3 (HC pore volume) or 6.6 MMmt.

For this initial project, the maximum volume of CO_2 injected p.a. will be 120,000 tonnes p.a., or 216,200 m^3 at reservoir conditions. In three years, this represents 0.65 MMm^3 or 5.4% of capacity and at 8 years represent 1.73 MMm^3 or 14.5% of the capacity. Figure 9.2 below illustrates the Hydrocarbon Pore Volume Map for the Precipice Reservoir.

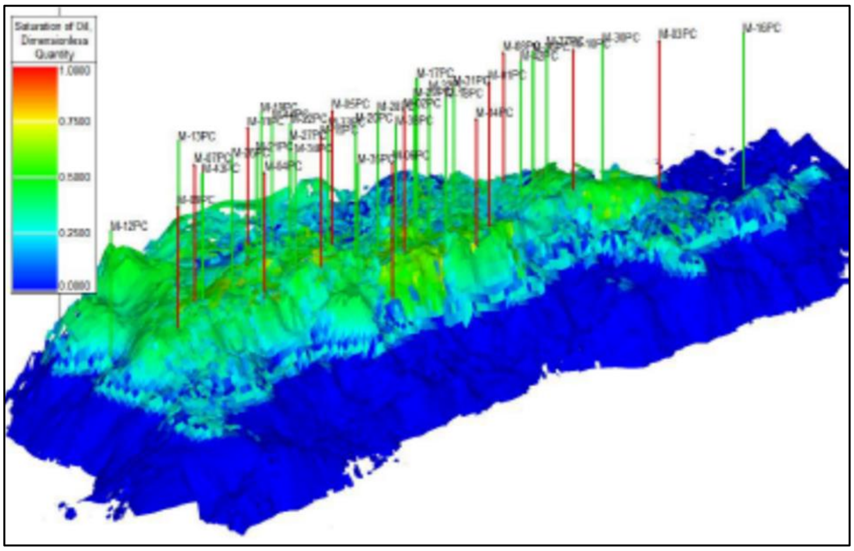
Figure 9-2, The Hydrocarbon Pore Volume Map for the Precipice Reservoir



9.4 CO_2 Injected Radius from the M27 injection well.

The overall Moonie Oil Field surface footprint is 4km by 16km. The injection well M27 is centrally located, and over 4 km from the sealed Goondiwindi Fault. Simulation of the oil, water and supercritical CO_2 ($scCO_2$) vector flows show the injected volume expansion around M27 will be approximately ~1200m X 400m. The injected $scCO_2$ does not approach the field limits. Figure 9-3 below illustrates this volume (light green) within the Moonie Oil Field.

Figure 9-3, Moonie Oil Field trap volume illustrated in light green



From the simulation model the injected $scCO_2$ cannot migrate outside of the initial project area as natural physical barriers prevent convection within the anticlinal restricted oil reservoir. Physically the $scCO_2$ is less dense than oil and water and does not migrate downwards in the pure state.

9.5 The Flow Vector Simulation Model

The flow vector simulation model predicts the injected volume remaining within the contained anticlinal reservoir (the Precipice “oily water leg”) and within the area of the initial project producing and monitoring wells over a period of eight years. The vectors calculated by the model are illustrated in the following Figures 9-4, 9-5 and 9-6. Note that the individual flow vectors represent modelled fluid movement. The size and number of lines are modelled representations of the volume and direction of movement resulting from local pressure gradients. All vectors flow towards the receiving production wells.

Figure 9-4 below, Illustrating the extent of CO_2 trapped at year three (2026).

Figure 9-4, the extent of the $scCO_2$ trap at end of year three.

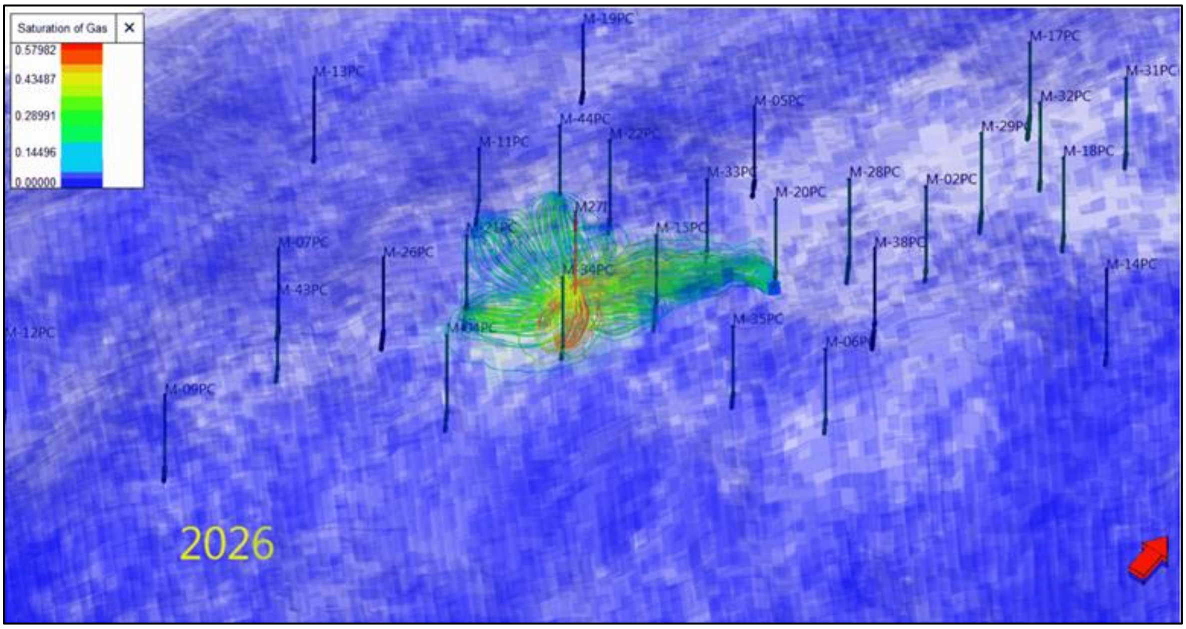


Figure 9-5 Illustrating the volumetric CO_2 trapped at end of injection in year eight (2031).

Figure 9-5, the volumetric CO_2 trap with the oil reservoir at end of injection in year 8

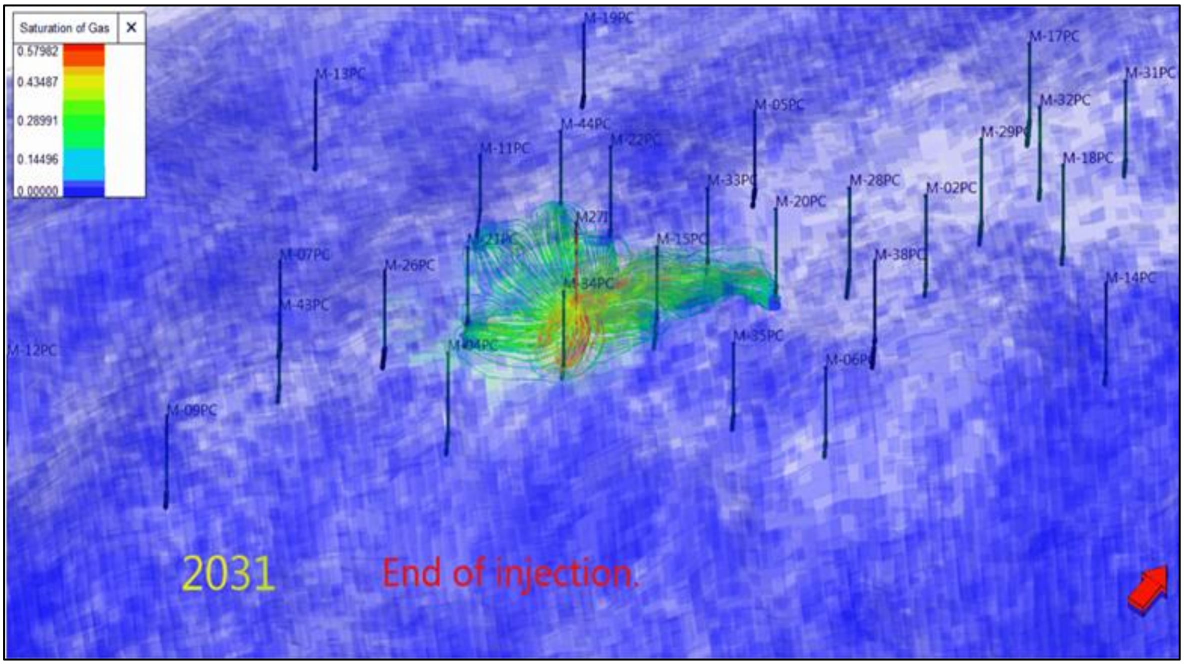
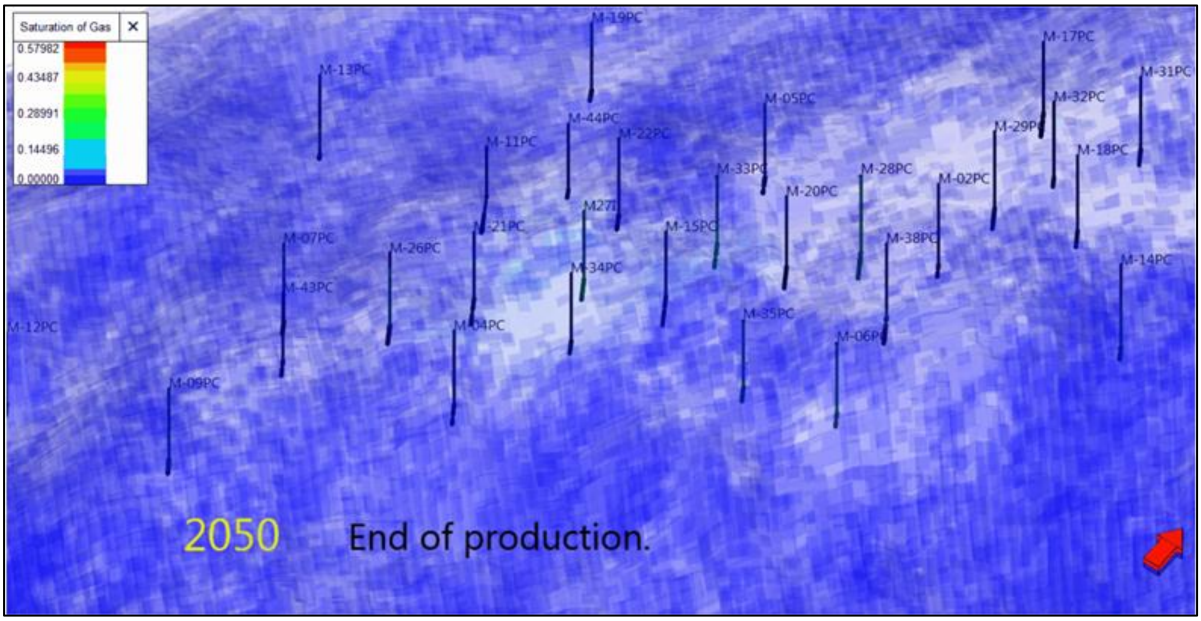


Figure 9-6 illustrates the volumetric CO_2 trapped within the oil reservoir at end of injection in year 2050.

Figure 9-6, the modelled volumetric extent of CO_2 in 2050



From the model the following figures 9-7, 9-8 and 9-9, illustrate the 3D saturation of CO_2 within the Precipice "oily water leg". At three years from commencement of injection, at the end of injection in eight years and at end of production in 2050.

Figure 9-7, 3D simulation of the extent of CO_2 saturation in the Precipice Oily Water Leg

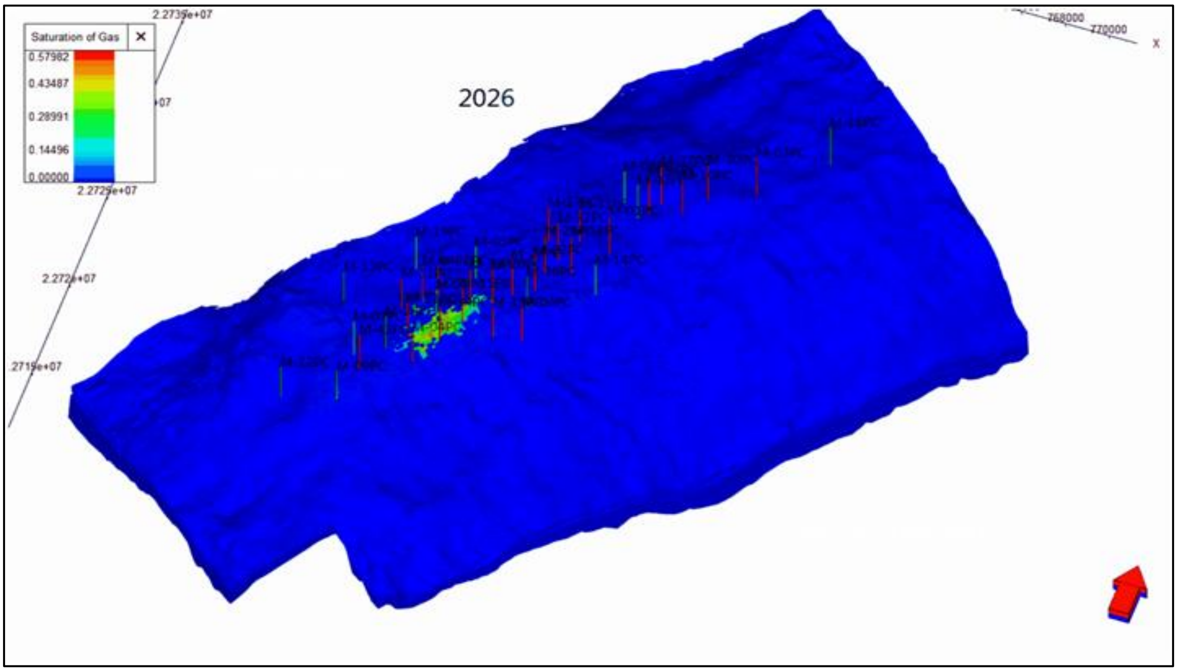


Figure 9.8, 3D illustration of the modelled CO_2 saturation in the Precipice oily water leg at end of injection

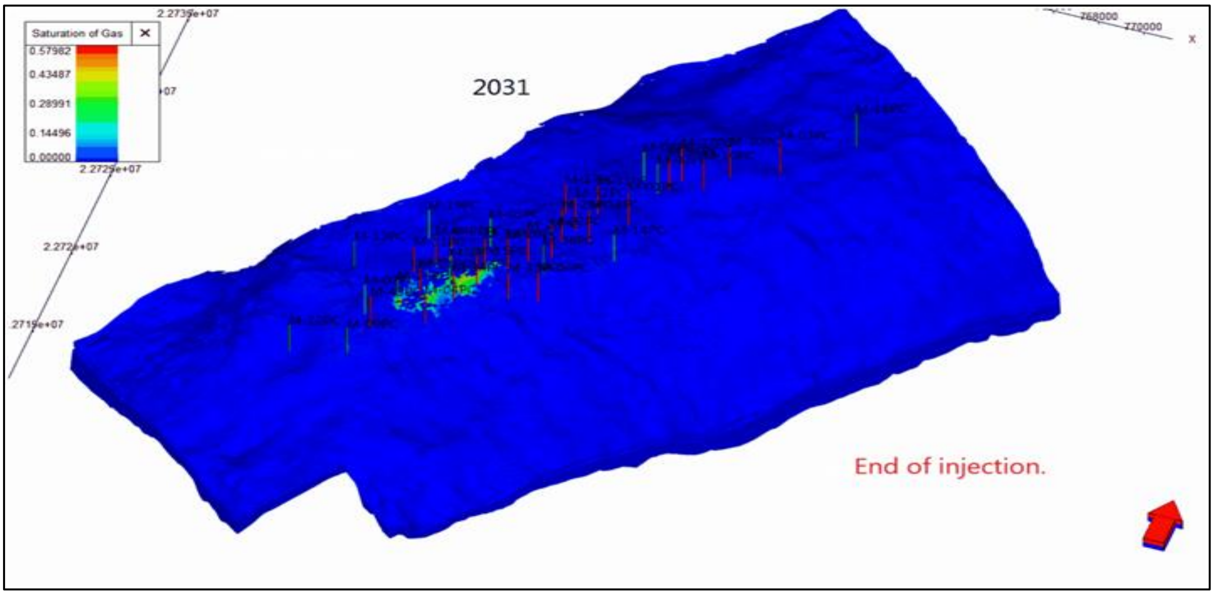
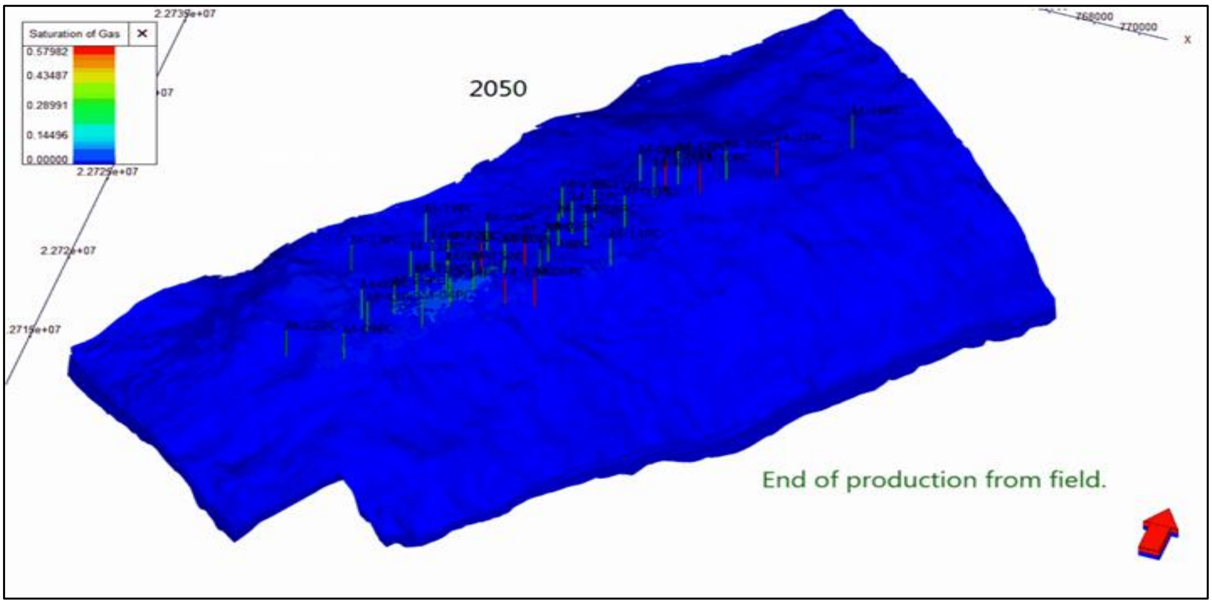


Figure 9.9, 3D illustration of the modelled CO_2 saturation in the Precipice oily water at end of production 2050.



The following figure 9-10, 9-11 and 9-12, illustrate the CO_2 saturation in 2D over the same time span.

Figure 9-10, from the model 2D illustration of CO_2 saturation at the end of 3 years of injection.

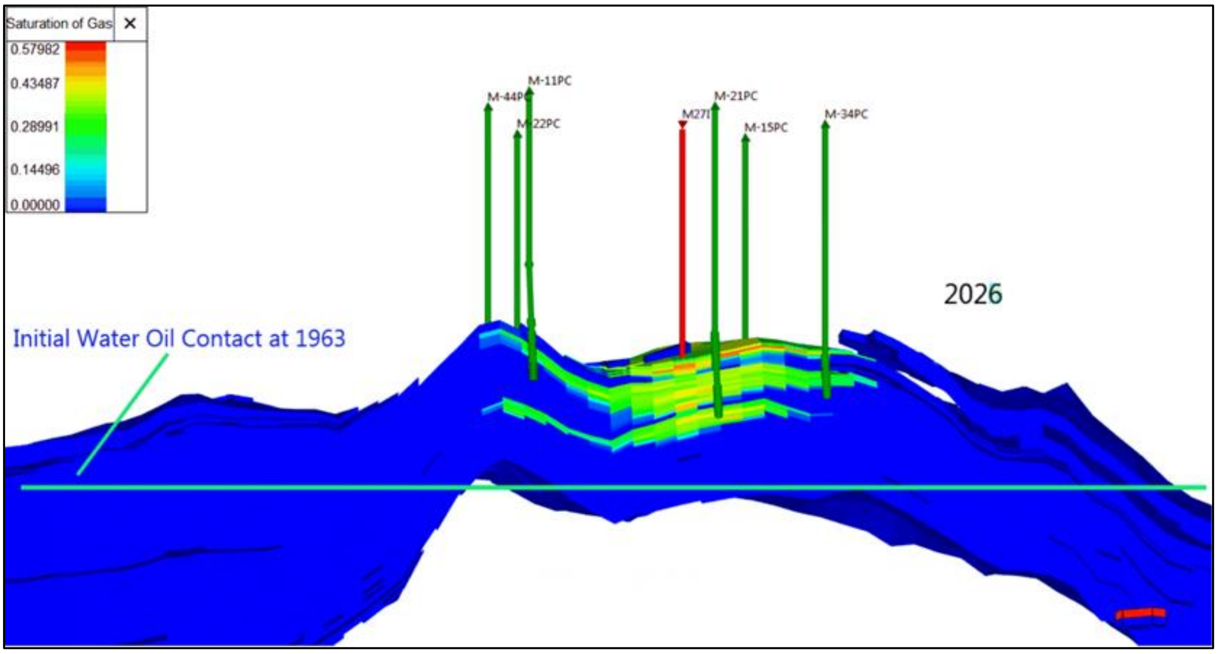


Figure 9-11, from the model 2D illustration of CO_2 saturation at the end of injection at 8 years

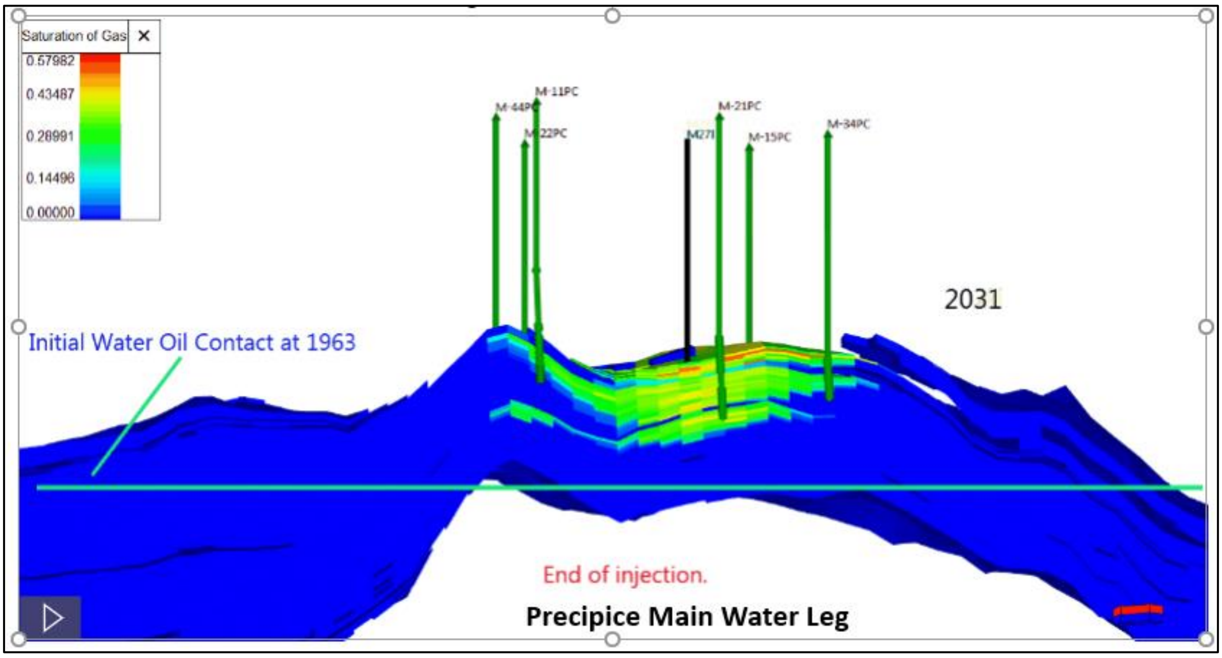
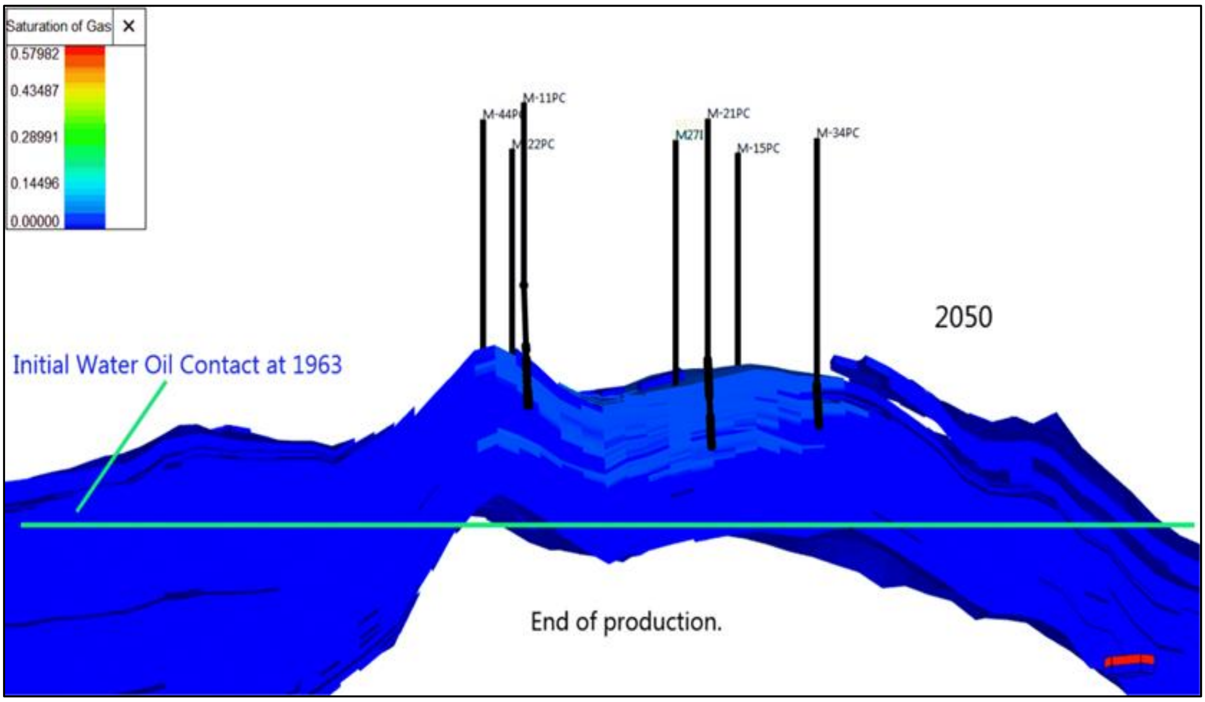


Figure 9-12, from the model 2D illustration of CO_2 saturation at the end of field production 2050



9.6 $scCO_2$ Phase Behaviour

The pressure of the CO_2 is increased from storage conditions, then pre-heated at surface prior to controlled injection to prevent thermal effects.

CO_2 remains in a supercritical state at reservoir conditions but will “gasify” within producing wells (post-emergence from the reservoir) as pressure reduces towards the surface. Similar in fashion to opening a carbonated drink.

Remaining CO_2 volume is entrapped in the oil reservoir and will compress/shrink after production ceases and reservoir pressure returns to original.

9.7 Relative densities of scCO2, oil and water

At reservoir conditions, $scCO_2$ is less dense than water and oil and will tend to remain at the top of the oil reservoir.

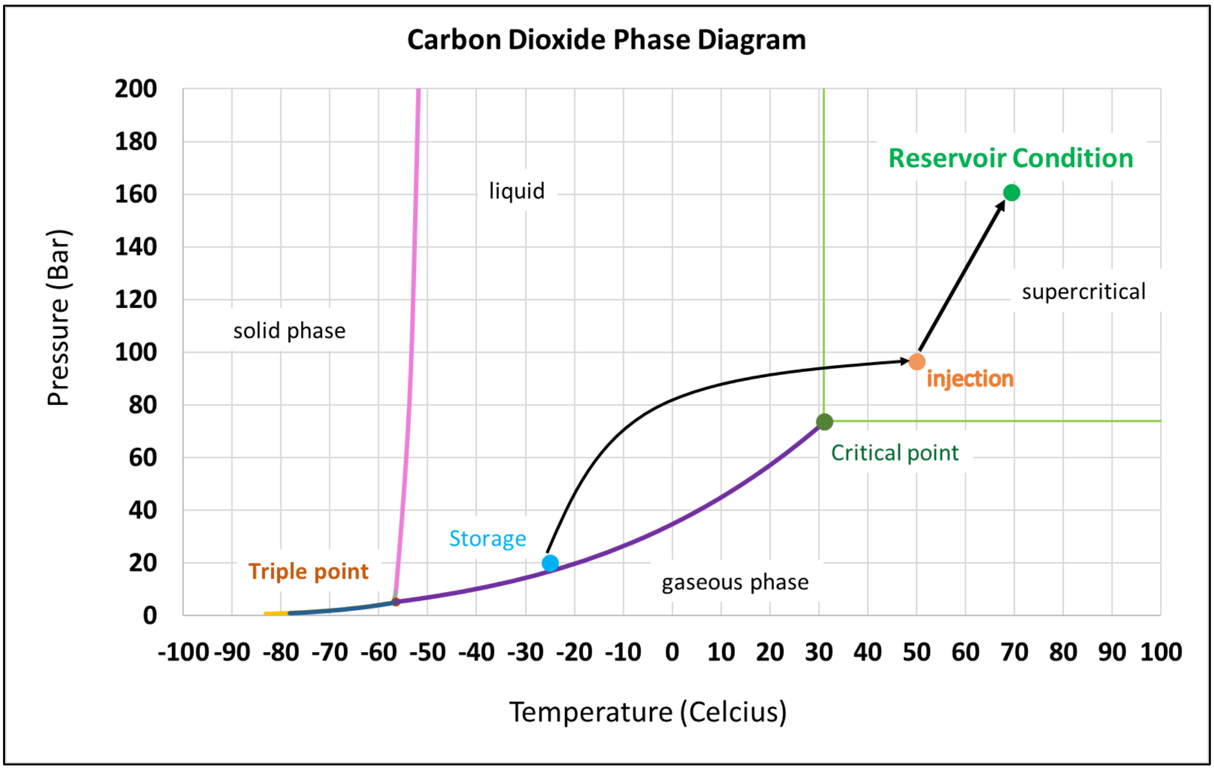
Table 9-2 below lists the various relative substance densities and illustrates the CO_2 density is lighter than oil or water and will tend to remain above the oil and water.

Table 9-2, Relative Densities of CO_2 Oil and Water

Relative Density	kg/m³
$scCO_2$	555
Moonie Crude Oil	741
Water	1,002

Figure 9-13 below illustrates the changes in CO_2 phases with changes in pressure and temperature.

Figure 9-13, The Carbon Dioxide Phase Change Diagram



"Supercritical CO_2 (scCO2)" is a fluid state of CO_2, where it is held at or above its critical temperature and pressure (the Critical Point). scCO_2 will expand to fill its container like a gas, but with a density like a liquid. The maintenance of the supercritical CO_2 phase is crucial to the EOR process whereby some of the oil fraction becomes more miscible and can flow to the receiving production wells.

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10.0 Executive Summary

- The team conclude there is no significant impact of CO_2 on environmental values through the controlled delivery of this initial injection project as detailed in Chapter 3: Initial CO_2 Injection Plan. Below are the key points for Chapter10,
- The delivered quality of CO_2 and other minor gases from Millmerran Power Station (being 120,000 tonnes p.a. i.e., 1million tonnes for eight years) have been defined below for the initial Moonie Initial CO_2 Injection Project. This represents a daily CO_2 injection rate of approximately 328 tonnes.
- The need for Australia to reduce the volume of CO_2 in the atmosphere is clearly established,
- The quality of the received CO_2 is very high (at 98%) and possible higher following commissioning of the PCC at the Millmerran Power Station,
- The background study substantiates very good air quality at the Moonie site,
- CO_2 already exists in the Moonie Oil Field anticline,
- The first 3 years of the project will see 20% of total CO_2 being released at surface via an exhaust venting system (being 24,000 tonnes p.a. or 72,000 tonnes over 3 years). This will increase the reportable Scope 2 emissions for the project and be reported on an annual basis. Over the eight-year life of the project 80% of the CO_2 will be sequestered being 768,000 tonnes in total.
- After 3 years it is proposed to assess the economic feasibility of 100% CO_2 capture, reinjection, and sequestration by installation of recycle equipment and compression at the Moonie field. This will capture additional CO_2 that would otherwise have been released, taking the injection site efficiency to nearly 100%.
- The release of CO_2 from the producing infrastructure at Moonie should not have any significant environmental impact and is a significant reduction from current 100% release levels at the Power Station,
- The study assumes the CO_2 gas detection threshold for monitoring to be 35 ppm,
- Hydrogen sulphide is present at 15ppm in the delivered liquid stream, the H_2S which survives chemical entrapment and appears at surface along with the CO_2 will be directed to the generators where it will be burnt. The product of burning H_2S is sulphide and water.
- University of Queensland (UQ) studies validate that no emissions of CO_2 have been recorded from soils or water tested in the project area. From the production records for the field our records indicate the emission of CO_2 from the existing Moonie oil field PM wells in normal operations at up to 5%,
- CO_2 monitoring will be undertaken at the injection well (M27) and the 5 surrounding producing wells,
- A report detailing the ongoing monitoring will be submitted to government on a half-yearly basis, see Chapter 5: the Moonie CO_2 Initial CO_2 Injection Project Monitoring Plan & Schedule,

- An Emergency contingency plan is in place which caters for emergency gas releases due to production upsets via a flare stack and venting system at the production facility.,
- Low impact dust emissions are expected during construction and are negligible during operations, and the Bridgeport Energy Dust Management Procedure applies as it does during normal operations.

This Chapter discusses,

- the assessment of air quality at the Moonie Oil Field,
- the quality of CO_2 being delivered,
- air environmental values,
- accidental releases and management,
- dust management, and
- monitoring requirements.

10.1 Introduction

The following air quality discussion has been created after reference to the Air NEPM (2016), the Air Toxics NEPM (2011), the QLD EPP (2008) and the Texas AMCV (2016a) and various Legislation.

10.2 Quality of CO_2 delivered to site from Millmerran

The following table details the high quality of the liquid CO_2 being provided by CTSCo from their post combustion capture (PCC)plant being constructed at the Millmerran Power Station. First CO_2 from that facility will be available in 2023.

Table 10-1 details the current gas quality specification from the PCC equipment specification (from CTSCo) being installed. This specification may vary during start-up and commissioning between the ranges shown below. Table 10 -1 details the gas quality data received from CTSCo.

Table10-1, Milmerran Power Station CO2 Gas specification

Constituent	CTSCo PCC Plant Warrantee Output Soec	CERI PCC Plant Actual Operating Data
Carbon dioxide	>98 vol%	>99.5%
Water	<150ppmV	<150 ppmV
N2/ Ar/ H2	< 2%	<0.5%
Other Hydrocarbons	< 0.1% v/v (1000 ppmV)	0
O_2	100 ppmv	~100- 400 ppmV
Carbon monoxide	200 ppmv	0
NOx (expressed as NO2)	33 ppmv	10~15 ppmV
SOx (expressed as SO2)	20 ppmv	2~5 ppmV
Particulate loading	10mg/m3	<5 mg/m3
Amines (MEA)	6 ppmV	~ 1ppmV
Ethyene Glycol	40 ppmV	0
Hydrogen Sulphide	15ppmv	0
Other externalities	Zero	0

Source: Glencore CTSCo July 2021

10.3 Delivery of CO_2 product from CTSCo

Bridgeport Energy will enter into a supply agreement with CTSCo the owner of the PCC plant being constructed at the Millmerran Power Station. This agreement specifies that CTSCo will have to present on delivery to the Moonie Oil Field a certified gas composition specification from a NATA accredited analysis laboratory validating that the quality of the $CO_2$and other gases being supplied matches or exceeds the product specification as detailed above. If it doesn’t then Bridgeport Energy can reject the delivery.

Table 10-2 below, details air quality environmental values in the Moonie field area.

Table 10-2, Description of Environmental Values, Air

Environmental Value	Description of Environmental Value
Climatic conditions	Climate of the Darling Downs in southern central Queensland is largely dominated by tropical/sub-tropical weather patterns that lead to relatively drier winters and wetter summers.
Average temperature	The annual mean maximum temperature reported between 1952 and 2012 was 28.2°C and annual mean minimum was reported to be 13.6°C
Average rainfall	The annual mean rainfall reported between 1870 and 2012 was 673.7 mm p.a.
Wind speed and direction	The annual wind frequency distribution indicates a predominance of south-westerly winds that persist throughout the day. However, a relatively high frequency of northerlies is predicted overnight, and strong north to north-westerlies are predicted each morning. During the afternoon, winds are at their strongest and mostly from southerly quadrants. In spring and summer, the strongest and frequent winds are from the north and in autumn, winds are predominantly from the south-eastern quarter. South westerlies are again predominant in winter
Air quality	The Moonie region of the SW Darling Downs enjoys very good air quality with most readings consistently below relative air quality objective (Air NEPM (2016) and Qld EPP (2008)), the modelled concentrations of air benzene and formaldehyde were very low and well below air quality objectives (Air Toxics NEPM (2011), Texas AMCV (2016a), albeit dust storms and bushfire smoke which has consistently reduced air quality periodically for 24-hour PM2.5 air quality objective

10.4 Assessment of Air Quality: Background discussion

Carbon dioxide (CO_2) is an important gas in Earth's atmosphere and forms approximately 3.14-4% of the atmosphere. CO_2 is an integral and key part of the biogeochemical carbon cycle, a cycle in which carbon is exchanged between the Earth's oceans, soil, rocks, and the biosphere. Plants and other photoautotrophs use solar energy to produce carbohydrates from atmospheric carbon dioxide and water by photosynthesis. Almost all other organisms depend on carbohydrate derived from photosynthesis as their primary source of energy and carbon compounds. CO_2 absorbs and emits infrared radiation at wavelengths of 4.26 µm (asymmetric stretching vibrational mode) and 14.99 µm (bending vibrational mode) and consequently is a member of the greenhouse gas group and plays a significant role in influencing Earth's surface temperature through the greenhouse gas effect.[1]

Ten thousand years ago the global mean CO_2 concentration was established from core analysis and other hindcast data to be at 280 ppm. This value was maintained and extended up to the mid-18th century and the start of the Industrial Revolution, when the global mean average concentration began to increase dramatically. The global concentration has progressively increased by 45% on average every decade since the Industrial revolution. It measured 415 ppm as of May 2019 with the current concentration being the highest for 14 million years.[23]

The increase of CO_2 and other long-lived greenhouse gases in Earth's atmosphere has produced the current trend and episode of global warming. Apart from the “greenhouse” effect of the immediate heating of air (which adds to the concentration of CO_2 in the atmosphere), between 30% and 40% of the CO_2 released into the atmosphere dissolves into the oceans, where it forms mild carbonic acid and creates changes in the oceanic pH balance which in combination with sea temperature warming ultimately alters world weather patterns.[4]

To reduce global warming the Australian “National Air Quality Agreement” was created by the Australian Government and the subsequent “National Air Quality Plan” was signed by all Australian States. The prime initiative is to reduce CO_2 emissions to the atmosphere with Carbon Sequestration being a main initiative. Carbon sequestration is a primary solution to help achieve the agreements to which Australia is a signatory (Paris and Rio agreements).

The Moonie Oil Field CO_2 EOR and sequestration initial project is one initiative that will significantly contribute to the direct reduction of CO_2 from the atmosphere in Australia.

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[1] *Petty, G.W. (2004). "A First Course in Atmospheric Radiation". Eos Transactions. 85 (36): 229–51. Bibcode: 2004EOSTr..85..341P. doi:10.1029/2004EO360007.*

[2] *"Trends in Atmospheric Carbon Dioxide". Earth System Research Laboratory. NOAA.*

[3] *Dlugokencky, E. (5 February 2016). "Annual Mean Carbon Dioxide Data". Earth System Research Laboratory. NOAA. Retrieved 12 February 2016..*

10.5 Environmental Values and Objectives: Air Quality

There is no human or animal exposure data for CO_2 in the Queensland Government's EPP Air guidelines. The natural concentration of carbon monoxide in air is around 0.2 parts per million (ppm), and that amount is not harmful to humans. The long term and short-term carbon monoxide exposure concentrations are 9 ppm over an 8-hour period and 35 ppm over a 1-hour period. It is reasonable to adopt this carbon monoxide exposure standard for the determination of air quality and gas detection devices at the injection site, in wellhead cellars and around the production facility will be used for measuring.

In the absence of any other industrial standards, Bridgeport will adopt the exposure standard above for CO_2. The CO_2 air quality monitoring threshold to be adopted and used around the well site initial project plant infrastructure will be 35ppm CO_2. Air meter quality checking will be undertaken when personnel are working in the areas above as they presently are for explosive gases.

10.6 Assessment of environmental impacts from the accidental release of CO_2

In the event of a liquid CO_2 release, the CO_2 will change from a liquid to a gas, diffuse and dissipate into the surrounding air, temporarily raising CO_2 concentrations in the very immediate area of release.

For this reason, a general safety zone of 3 metres around the injection wells, consistent with safety hazard drawings for the facility producing and monitoring wells and applicable plant will be maintained. A windsock on site at the production facility provides the down-stream wind direction will also be employed subject to site operations requirements.

The release of gaseous CO_2 to the atmosphere will not have a major atmospheric environmental impact and would dissipate into the atmosphere representing the same volume of CO_2 from industrial sites found elsewhere. The following Table 9-3, CO_2 ambient air quality objectives, illustrate the air pollutant objectives that may be used for the initial injection project plant operation.

Under normal pilot plant operations there will be no adverse impact to the environment. No adverse environmental impact by the temporary release of CO_2 has been assessed.

[4] *Millero, Frank J. (1995). "Thermodynamics of the carbon dioxide system in the oceans". Geochimica et Cosmochimica Acta. 59 (4): 661–77.*

Table 10-3, Target CO2 Ambient Air Monitoring Quality Specifications

Gas	Environmental Value	Averaging Period	Air Quality Objective (Exposure) at 0°C	Source of Objective
CO_2	Health & well being	1 hour	9ppm	US EPA
CO_2	Health & well being	8 hours	35ppm	US EPA

10.7 H_2S in the fluid stream

Hydrogen Sulphide will be present in the injection fluid stream (7-15ppm) and will react with water to form a weak acid (sulphuric acid) and associated ions (this process is detailed in Chapter 8 section 8.4). This then will react with carbonate-based elements and be neutralised and buffered. Chemical entrapment mechanisms discussed in Chapter 8, section 8.5.2, and 8.5.3 will trap products from the H_2S and water, however any H_2S gas which survives in the fluid stream presenting at surface will be directed and burnt in the generators. The process of burning dissociates the H_2S into Sulphur and water. For further detail see Chapter 8 section 8.4.

10.8 Dust Management

Dust emissions from the Project, including PM10 and PM2.5, will be nil as the CO_2 is injected. However, during construction and to a much lesser degree once the facilities are operational, minor dust will be generated by vehicles gaining access to the site on unsealed access tracks. The "Bridgeport EMP" details dust management control procedures and they are summarised below,

1) In windy conditions greater than 15 knots, with consistent vehicle movements apply production water sufficient to control dust emissions (existing approved EA condition) as required. The reduction of vehicular speed to less than 20km/hr while on site,

10.9 Assessment of environmental impacts of dust

Given the implementation of the Bridgeport EMP summarised above no adverse impacts from dust emissions should occur.

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11.0 Executive Summary

From a Geological and Geomorphological perspective this Chapter discusses the potential impact of injection of CO_2 into the Precipice reservoir (Table 11-1).

The studies undertaken by University of Queensland (UQ) and Bridgeport have determined several essential management practices related to injection management that will preclude environmental impact on local geological aspects.

These management factors include;

1. Validation of the maximum injection pressure and volume thresholds,
2. Determination of the optimum CO_2 bottom hole pressure and injection temperature,
3. Surveys of the existing wells at Moonie comprising one Injection well and five Production and Monitoring wells (PM wells) to validate their production casing integrity,
4. A monitoring program initiated at the PM wells, to confirm the critical production parameters, e.g., the temperature, pressure, pH, water quality, GOR ratio and gas content,
5. The swap out of internal tubulars with CO_2 resistant metal tubing and isolation packers, initially at the injection well (M-27) and later as assessed at each of the PM wells based on corrosion rates,
6. Conversion of the 5 PM wells from monitoring to monitoring and production wells, and
7. Construction of the surface CO_2 infrastructure to Australian Standards and industry best practice.

In summary no adverse impacts are expected if the above proposed controls are implemented.

11.1 Environmental Value & Objective

The primary objective of this initial injection project within the Precipice Sandstone is to minimise potential impact on the receiving geological interval, while validating the CO_2 injection model.

11.2 Environmental Assessment

The following factors generated by previous DES discussions and workshops relate to potential impacts, which are then assessed in Table 11-1,

- Fracture zones, joints and lineaments
- Fault slip analysis,
- Downhole pressure may cause breakout upwards through cementation around the immediate borehole area,

- Formation fracture pressure exceeded by excessive bottom hole pressure,
- Injection temperature introduces fractures,
- CO_2 temperature and potential impact on upper seals,
- Geomechanical properties,
- Reservoir scaling,
- Seal fracture potentially brought about by CO_2 over pressuring,
- Geochemical degradation of the seal rock (by mild acid),
- Loss of well integrity possibly leading to a significant loss of containment,
- Changes in porosity and permeability due to chemical change, impacting reservoir pressure,
- Increased reservoir pressure impacts local boreholes by increasing the water column,
- CO_2 migration along potential lineaments into other aquifers,
- Change in pressure propagates old fractures, or reactivation of faults,
- Pressure at a vulnerable point such as an improperly abandoned well or a fault line bisecting or crossing a formation seal

11.3 Introduction

Table 11-1 identifies the environmental values/aspect and links mitigating control to each value to reduce the risk to ALARP and best industry practice.

Table 11-1: The Environmental Assessment of Geological Aspects.

Geological Aspect	Associated Risk as identified by DES	Potential Impact	Operations Mitigating Control	Residual Risk Rating
Fracture Zones, Joints and Lineaments	Fracture zones and joints and other lineaments are potential conduits for CO_2 and fluid flow both natural and induced.	CO_2 has the potential to migrate along major fracture zones and other lineaments	Pearce *et al* and Hayes *et al* (UQ) conclude from their assessment that the existing fracture zones and lineaments are locally restricted and self-sealing. The major fault zone is several kilometres from Moonie 27 and is assessed as having negligible impact with the pilot project. (For further discussion refer to Chapter 6 Geology)	Low
Fault Slip Analysis	Injection pressure induces fault slip	Potentially this could cause inter aquifer flows	Fault slip analysis using the UQ Monte Carlo simulation suggests the pressure at which fault slip would occur would be higher than the bottom hole pressure of any injection well and is thus not a significant risk to this injection project. Further, during the initial phase the CO_2 does not reach the fault area.	Low

Table 11-1: The Environmental Assessment of Geological Aspects.

Geological Aspect	Associated Risk as identified by DES	Potential Impact	Operations Mitigating Control	Residual Risk Rating
Downhole Pressure causes breakout upwards around the immediate borehole area.	The greatest pressure will be at Bottom hole.	Downhole pressure causes interconnectivity between formations	The design of the downhole outer casing cement seal is sufficient to prevent breakout upwards along the borehole Concrete used in the outer concrete seal is resistant to mild acids Downhole packers are used as a passive control to isolate the casing annulus from CO_2 or hydrocarbon The pressure and temperature of the CO_2 being injected is monitored within pressure thresholds to prevent upwards migration of CO_2 Given the thickness of the transition zone both below and above the seal, there would be insufficient pressure or chemical reaction to break through the seal. Cement Bond Logs (CBLs) will be run at the injection and PM wells during the validation of well integrity prior to commencement and as part of the contingency plans discussed in Chapter 3.	Low

Table 11-1: The Environmental Assessment of Geological Aspects.

Geological Aspect	Associated Risk as identified by DES	Potential Impact	Operations Mitigating Control	Residual Risk Rating
Fracture Pressure: The pressure at which the formation rock fractures.	Rock will fracture above 50.9MPa	Above this pressure the rock will fracture away from the immediate injection zone permitting migration of $scCO_2$ into other formations	The bottomhole pressure will be limited to at least 90% of the actual formation fracture pressure plus a thermal factor. This safety margin has been used in Canada (Bachu and Gunter 2005). (for further discussion refer to Chapter 3)	Very Low
Geochemical degradation of the cap rock by mild acid and loss of well integrity could lead to a significant loss of containment	CO_2 could escape through seals through hydro chemical reactions, i.e., dissolution of susceptible minerals	A conduit could be potentially established between aquifers	Pearce *et al* (2019) ascertained at UQ that the volume of $scCO_2$ is insufficient to create a massive hydro-chemical reaction breaking down the transition zone and seals. The modelling concludes that over 1,000 years the pH may change slightly to between 5- 5.5 range with injection of the millions of tonnes of CO_2 contemplated in their model. The pilot trial is designed to inject only 0.09% of this volume, a negligible impact on pH given the reservoir pressure, strong fluid drive (mixing ability) and the resultant dilution pressure. A reaction with the CO_2 flood front will occur with the contact front of the transition zone and with the seal and will not penetrate the actual seal or Precipice lower water zone.	Low to negligible

Table 11-1: The Environmental Assessment of Geological Aspects.

Geological Aspect	Associated Risk as identified by DES	Potential Impact	Operations Mitigating Control	Residual Risk Rating
Temperature and Bottom Hole Fracture Pressure impact on downhole injection zone	If the CO_2 temperature being injected is -25°C in an 80-100°C formation, the injection of CO_2 will precipitate cooling at Bottom hole and according to Rodger *et al* (2019), will have an impact of decreasing the fracture pressure, i.e., potential to form local micro-fractures	Thermal Impact at the bottomhole creates fractures in the immediate zone that extend upward into the seals.	Rodger *et al* (2019) advises reducing the injection pressure to establish a safety margin. So, adjusting the bottom hole pressure to a maximum of 39,753kPa on a thermally adjusted basis. The temperature of the injected CO_2 will not be -25°C in any event as the warming effect and time to inject downhole will bring it to near reservoir temperature. The potential of local micro-fractures to cause inter-aquifer impact is negligible as the temperature effect dissipates with distance from the injection zone and is a function of the temperature, the porosity, and the permeability in the immediate injection zone.	Very Low

Table 11-1: The Environmental Assessment of Geological Aspects.				
Geological Aspect	**Associated Risk as identified by DES**	**Potential Impact**	**Operations Mitigating Control**	**Residual Risk Rating**
Temperature and potential impact to aquifer seals	The change in temperature brought about by injection causes a break in aquifer seals	A break in aquifer seals could potentially lead to a mixing of aquifer waters	Given the depth of the transition zone between the Precipice Sandstone and upper ultimate seal (100m+), and due to the distance between the injection depth and the upper or lower seal, Rodgers *et al* (2019) suggests there is no impact on the upper ultimate seal by upward rising thermal change resulting from the injection process. Rodgers (etal 2019) recommends a further 14.5% reduction in injection pressure to avoid the temperature effect. The injection pressure will be kept below a pressure where potential temperature impact could occur, i.e., 39,753 kPa. The injection temperature is a function of injection rate and will be close to reservoir temperature on injection based on a 45min to 60min transit time to the reservoir at planned injection rates.	Very Low

Table 11-1: The Environmental Assessment of Geological Aspects.				
Geological Aspect	**Associated Risk as identified by DES**	**Potential Impact**	**Operations Mitigating Control**	**Residual Risk Rating**
Shear Slip Various studies have indicated a thermal impact on seismic activity and faults.	Geomechanical fault slip	Water could transfer between aquifers	Rodgers et al (2019), has dismissed this effect, as the distance from the injection point to the fault and the subsequent heating, dissipates with distance from the injection point will have no adverse impact.	Negligible
Geomechanical Properties if the Precipice Sandstone did not have its unique mineralogy then the cementing reaction would not occur	Minor alteration of plagioclase and K-feldspar to kaolinite, chalcedony and ankerite in cleaner Moonie sandstones, with additional precipitation of smectite in clay rich sands resulting in potential changes to the seals	Formation water pH will be buffered between 5 and 6 caused by dissolution of calcite or siderite cements. Sampled core has also shown evidence of previous natural CO_2 and hydrothermal fluid alteration, fractured quartz grains, and fracture fills with mineral trapping as carbonates.	Rodgers et al (2019) clearly established the presence of high bicarbonate in the aquifer, and addition of CO_2 could increase the amount of buffering bicarbonates and the presence of elements used in further sealing, especially in the transition zone.	Very Low

Table 11-1: The Environmental Assessment of Geological Aspects.				
Geological Aspect	**Associated Risk as identified by DES**	**Potential Impact**	**Operations Mitigating Control**	**Residual Risk Rating**
Reservoir scaling from potential change in pH brought about by injecting CO_2	The injection of CO_2 could potentially produce further reservoir scaling	Reservoir scaling could potentially change reservoir pressure	There is insufficient volume of injected CO_2 to make an impact. The studies undertaken indicate the action of scaling tend to further seal transition zones.	Very Low

The potential of CO_2 leaching into other formations	CO_2 permeates into other aquifers	Given the seal and the thickness of the transition zones between the Precipice and Evergreen Members and their low permeability the potential for CO_2 to leach is small. No adverse impact is expected. Pearce *et al* (2019) has conducted acid impacts on Moonie core samples and concluded that while there may be a chemical reaction with mineral elements in the seals, minor fractures and the greater rock formation where contact is made with the weak acid, the resultant end products are expected to increase the seal.	Greater than 1,400-1,800m of vertical separation exist between the target reservoir and surface. The chance of penetration is very low due to the number, the type and number of seals and transition zones between each aquifer. Monitoring of the reservoir situation threshold via the monitoring boreholes will be ongoing and should a change in a monitoring parameter occur then it will be shut down until it is remedied, see Chapter 3: Contingency Measures. The absence of geological structures such as faults and other connecting features that could connect the Precipice Sandstone to overlying groundwater aquifers precludes the potential for CO_2 to leach into other formations. The seals in the Moonie Field are sufficiently effective such that no oil or gas has ever breached the traps for 90 Ma years to allow any escape to the surface. UQ studies of the surface region including the local streams and surface including the Moonie oil Field did not discover any evidence of oil or gas (from oil) seeps.	Very Low
Over pressure causing breaks in existing	Over pressure of the target formation generating	The potential escape of CO_2 into other formations and mixing with another aquifer	The bottom hole injection pressure will be closely monitored to ensure that over pressure does not occur.	Very Low

Table 11-1: The Environmental Assessment of Geological Aspects.				
Geological Aspect	**Associated Risk as identified by DES**	**Potential Impact**	**Operations Mitigating Control**	**Residual Risk Rating**
Formation seals.	fractures into overlying formations.		The injection surface pressure will be controlled and governed to ensure pressure does not exceed fracture gradient. Downhole pressure will also not exceed the fracture pressure of adjacent formations as these zones are not depleted. Any induced micro fractures will tend to propagate along and within the target formation. There would be insufficient pressure to induce fractures to propagate into non-target formations located above and below the target formation. As a failsafe Rodger (2019)[1] recommends setting the injection pressure at 39,753 kPa. Process controls will be in place to ensure injection pressures do not exceed this maximum limit and will be continuously monitored and adjusted as required. Production monitoring will take place in the adjacent wells to assess reservoir pressure and fluid response.	

[1] *Rodger etal 2019a, UQ-SDAAP – Pressure constraints on Injection, Technical Report April 2019*

Table 11-1: The Environmental Assessment of Geological Aspects.

Geological Aspect	Associated Risk as identified by DES	Potential Impact	Operations Mitigating Control	Residual Risk Rating
Changes in porosity & permeability impacting reservoir pressure	Potential breakthrough from one aquifer to another	Potential mixing of aquifer waters	No major change in reservoir porosity or permeability will create a breakthrough from one aquifer to another as the horizontal permeability is significantly higher than the vertical permeability.	Very Low
Increased reservoir pressure impacts local boreholes	Local farmers can't withdraw water and must lower their bore pumps	Depth of water in local boreholes declines realizing community impact	Ribeiro *et al* (2019)[2], proposed a model for the injection of 273 Mt of CO_2 into the Surat and predicts a positive impact on local boreholes, overtime the model predicts an increase in borehole water levels. The proposed pilot amendment is 0.09% of the volume above and as such will have no impact on the levels of water in local boreholes. Hayes et al (2019)[3] discusses the effect of salinity and temperature relative to the injection pressure. Given the lower volumes used in the initiation project, Bridgeport predicts no adverse impact will occur. The closest large-scale water bore to the Precipice is 110km from Moonie and as such injection at Moonie will have no impact.	Very Low

Table 11-1: The Environmental Assessment of Geological Aspects.				
Geological Aspect	**Associated Risk as identified by DES**	**Potential Impact**	**Operations Mitigating Control**	**Residual Risk Rating**
Change in pressure propagates old or new fractures, reactivation of faults		CO_2 and other aquifer waters could potentially mix as old fractures are forced open by overpressure.	The injection pressure will be set within pressure parameters discussed in Chapter 9 Petrophysics, so that a sufficient margin is kept, avoiding the reactivation of any internal faults. The recommended thermally adjusted injection pressure is 37,753 kPa. (for further discussion refer to Chapter 3 and 9) There is no evidence in the Moonie field of internal faulting from seismic interpretation (simply the Moonie Goondiwindi sealing fault to the west), however should there be any internal sub seismic faults activation pressures will be well below that that could activate faults.	Negligible

[2] *Evaluating performance of graded proppant injection into a CSG reservoir: a reservoir simulation study, Riberio etal, Unconventional Resources Technology Conference & Proceedings, 2019*

[3] *Hayes etal 2019, The U f Q Surat Deep Aquifer Appraisal Project (UQ-SDAAP) Scoping study for material carbon abatement via carbon capture and storage, Supplementary Detailed Report, Regional groundwater model.*

11.4 Assessment of environmental impacts: Geology

Apart from determining the maximum amount of CO_2 to sequester, this initial injection project will assess the capability to inject CO_2 into the Precipice “oily water leg”, in the Moonie Oil Field. Oil from the Moonie Field has been extracted since 1969. Replenishing with liquid CO_2 should in time restore the reservoir pressure towards the original reservoir pressure, however, the modelling indicates that this will not occur till after the cessation of pumping.

The studies undertaken by University of Queensland (UQ) and Bridgeport have determined several essential management practices related to injection management that will preclude environmental impacts.

These management practices include;

- Validation of the maximum injection pressure and volume thresholds,
- Determination of the optimum CO_2 bottom hole pressure and injection temperature,
- Surveys of the existing wells at Moonie comprising one Injection well and five Production and Monitoring wells (PM wells) to validate their production casing integrity,
- A monitoring program initiated at the PM wells, to confirm the critical production parameters, e.g., the temperature, pressure, pH, water quality, GOR ratio and gas content,
- The swap out of internal tubulars with CO_2 resistant metal tubing and isolation packers, initially at the injection well (M-27) and later as assessed at each of the PM wells based on corrosion rates,
- Conversion of the 5 PM wells from monitoring to monitoring and production wells, and
- Construction of the surface CO_2 infrastructure to Australian Standards and industry best practice.

In summary no adverse impacts are expected if the proposed controls (above) are implemented.

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Chapter 12: Assessment of Impact: Groundwater

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12.0 Executive Summary

This Chapter examines the assessment of the potential impacts to groundwater environmental values. The groundwater environmental values are established in the initial part of the chapter while Table 12-1 lists the potential impacts and mitigating controls to reduce the risk by employing best industry practice.

The key points for this chapter are:

- There are several existing groundwater controls in the current Environmental Authority which Bridgeport Energy will continue to comply with and extend to this project.
- Chapter 7 clearly established the existing Precipice “oily water leg” (>1.5km sub-surface) ground water quality as not being pristine, being characterised as “disturbed” and containing several impurities not conducive to surface use (being an oil reservoir). Indeed, there are several far superior and shallower groundwater sources which are currently accessed by preference by landholders.
- The Precipice “oily water leg” ground water is confined within the folded Precipice formation forming an Anticline within which the movement of groundwater is prevented by restricted upward permeability, natural barriers consisting of impermeable seals and thick aquitard sequences (detailed in Chapter 6,7 & 9).
- University oof Queensland (UQ) studies have shown there is no connectivity with the surface or surface waters.
- The original UQ groundwater reservoir model (2019) has been used to predict various outcomes of injecting CO_2 into the Precipice “oily water leg” residing in the Moonie Anticline, with an initial volume of 3 MMscf/d. At the reduced injection rate of 120,000 tonnes per year the effect on local water column height will be minimal, if detectable. Post injection, and post oil retrieval the model indicates the water column height will be the reservoir average height.
- Because of the decreased volume being injected in this initial project and the effect of the presence of carbonates, the temporary impact on downhole pH will be significantly less than originally predicted with the lesser injection volume. The model estimates a temporary pH change from 8 to 5-5.5. Post injection the model indicates the pH returning to normal reservoir conditions over time. This will be monitored as the project continues.
- The ions formed by the CO_2 reacting with water will be buffered by the high presence of carbonates in the groundwater which has accumulated in the Moonie anticline for more than 90 Ma (refer to Chapter 8 Groundwater Geochemistry).

12.1 Introduction

The groundwater environmental values are listed as,

- Maintaining the integrity and water quality of surrounding aquifers by preventing the flow of CO_2 into other major aquifers,
- Post artificial lift, within 6 months validating the CO_2 remains within the Moonie anticline,
- Implementing the water conditions listed in the Environmental Authority.

12.2 Direction of water flow in the Precipice at Moonie 27.

On a reservoir basis the flow of water in Precipice sandstone is entirely from the northern and north-eastern intake areas where the reservoir recharges, flowing towards the south to southwest. The barriers to flow are the Auburn Granite and a subsurface divide (the Kumbarilla Ridge) acting as a barrier to the east, and the Nebine Ridge as at least a partial barrier to the west.

The reservoir oil/water contact conforms to the general basinal pattern. The original tilt to the field is very near zero. There will be no change to flow or flow direction by this initial CO_2 injection project.

12.3 Groundwater Reservoir Model

A regional reservoir model was created by UQ-DSAAP, incorporating the Moonie Oil Field, using a daily injection rate of 3 MMscf/d of CO_2 and tested for potential impact on local borehole water elevations and pressures over time using various bottomhole injection pressures. Several million tonnes were theoretically injected and modelled over a time span of up to 1,000 years with the result over time showing a gradual uplift in borehole water level elevation (good for local farming activities) and in the longer term a return to current borehole water elevations due to the reservoir returning to equilibrium post injection.

This initial CO_2 injection project plans to inject a significantly lower volume of CO_2 being approximately 120,00 tonnes p.a. (0.09 % of the volume modelled above). Considering the significantly lower volume being injected no adverse impact to bore hole water levels in the area has been predicted by the model.

12.4 Groundwater pH

For the larger volume model used in the UQ regional model (3 MMscf/d of CO_2, Pearce et al. 2019), the CO_2-water-rock predictions indicate formation water pH decreased in the Moonie Precipice Sandstone ('58 sands') but was buffered by a higher dissolved bicarbonate content and by mineral dissolution to pH 4.8 and returning to 5.3. and in time to reservoir conditions. Given the pilot will be 0.09 % of the original modelled CO_2 injection volume, the change in pH will be significantly less, if detectable, in the initial CO_2 injection trial. With the addition of $scCO_2$, the pH is buffered to a pH of 5-5.6.

12.5 Mineral Content

The Precipice “oily water leg” contained in the Moonie Anticline contains carbonates, ankerite and minor kaolinite, being precipitated in cleaner sandstones, with smectite in clay rich sandstones and shales. Precipitation of smectite is likely to maintain or improve sealing capacities of clay rich seals and may adsorb CO_2.

The predicted dissolution of carbonates and feldspar is consistent with observations from experimental relative permeability reactions performed as part of the UQ-SDAAP and other projects. Precipitation of Kaolinite, Ankerite, Smectite is consistent with observations from sites of natural CO_2 alteration.

Natural CO_2 and hydrothermal fluid alteration, fractured quartz grains, and fracture fills with mineral trapping as carbonates has been observed in core samples throughout the basin. The pilot project is only 0.09 % of this volume and should have a significantly lower impact than the UQ model, Pearce et al (2019).

12.6 Formation Seals

Every geological seal has a characteristic hydrological data set above and below the seal. The impermeable seal unit at the Moonie Oil Field is the Evergreen Formation consisting of marine lacustrine shale and siltstone with sandstone towards the top.

The seal type is a conventional shale/siltstone seal, its thickness being 20-100m (dependent on location) and its seal effectiveness is ranked by UQ as 3 (3 being the upper effectiveness ranking).

The ideal injection pressure should not exceed the fracture pressure, so the injection pressure to achieve miscibility is > 16 MPa and < 31 MPa. The pressure statistics are detailed in Appendix A.

This initial injection project is expected to have negligible impact representing 0.09 % of the Pearce et al. (2019) modelled volume. The general small pressure increase at larger scale and volumes, is seen by Hayes etal (2019) to be a net benefit and positive impact, helping the pressurisation of the aquifers local water column heights to increase due to localised pressure which will have lower beneficial pumping costs to landowners.

12.7 Environmental Value & Objectives: Groundwater.

The activities listed and identified by DES below involving groundwater management have potential to impact upon environmental values, they include:

- potential escape of CO_2 through outer concrete encasement of the production casing due to overpressure or degraded well integrity resulting in CO_2 at surface,
- breaching of production casing due to potential injection overpressure,
- combination of CO_2 with water causing acidity in the local injection and receival area, resulting in the corrosion of production casing and tubulars,
- potential impact of CO_2 on microorganisms in the Precipice Formation,
- mild acid formed from CO_2 & H_2S impacting on the reservoir seal,
- Bottom hole temperature influencing the integrity of upper and lower formation seals and transition zones,
- Leaching into other formations due to leakage out of the constrained reservoir through formation seals,,
- Injection process may impact on water supply boreholes outside the project area and reservoir, and
- Impact of extraction activities whereby CO_2 escapes in large volumes through the PM and other local offset oil collection wells.

The assessment of the above potential impacts on environmental values is summarised below in Table 12-1 overpage.

Activity	Associated Risk	Potential Impact	Mitigating Control	Residual Risk Rating
Potential breaching of casing due to overpressure	CO_2 escapes into the atmosphere	The CO_2 could breach through the inner chrome-based tubing or isolating packer and enter the annulus between the casing and the tubing and escape to surface.	• Undertaking pressure logging evaluation and testing of production casing to confirm integrity of production casing and tubing in existing wells, • Continuous production casing pressure monitoring, in particular of the injection well, to ensure no production casing integrity failures and a potential leak path into the surface casing. • Injection pressure limited to below 80% of the tubing and isolation packer yield pressure. The injector well Moonie-27 has 5-1/2" 17 lb/ft J-55 ST&C casing as the production casing, as new it has an API burst yield pressure of 5,320 psi. at 80% the yield pressure will be 29,344 kPag or 4,256 psi. • At the M27 injection well, continuous injection pressure monitoring with upper limit process controls will be in place to stop injection should pressure exceed the specified operating envelope (see Appendix A) Incorporation of a high-pressure alarm and trip on the injection pump will ensure pressure remains below well below tubing/packer casing yield pressure.	Low

CO_2 combining with water to cause acid conditions in the Precipice Formation – main water leg (water aquifer).	Small, localised area of effect	The receiving groundwater quality is adversely changed.	• The Great Artesian Basin including the Precipice Formation aquifer outside the Moonie reservoir, is the size of 130,000 Sydney harbours or 65M GL and the volume of liquid CO_2 injected will be 120,0000 tonnes, or 0.00001 % of the GAB volume. Pearce *et al* (2019) has calculated that the injection of 3m tonnes per annum of CO_2 could reduce the pH to 5.5 over 1,000 years. The volume of this initiation project is proposing to inject over 8 years is 0.09 % of the original volume contemplated by Pearce, therefore having negligible adverse impact. • Local impact is not significant as liquid CO_2 is being injected into the oil reservoir, which already contains oil, water, and other chemicals. • The CO_2 will initiate a number of chemical reactions described in Chapter 8 whereby a mild acid formed and undergo a reaction with the minerals and carbonates present, effectively trapping resultant products, improving the seal integrity and buffering the pH change (refer to Chapter 8). There will be no adverse impact. • Pearce *et al* (2019) observed that the relatively high reservoir pressure and recharge pressure coupled with high bi-carbonate nature will significantly reduce or nullify the propensity to create acidic conditions away from the bottom hole injection point. • Due to past extraction of oil and water (60MM tonnes) there is a significant volume within the Moonie anticline to accommodate the proposed injection of 120,000 tonnes CO_2, with only 2% of the potential pore volume being displaced in the reservoir over the eight years of injection of this initial project. • No mitigation methods are proposed other than monitoring	Very Low

Impact of CO_2 on microbes	Anaerobic hydrocarbon degradation is a common process in biodegraded subsurface oil reservoirs, the presence of more acidic conditions may reduce this adverse impact, (Aitken et al 2004, Anaerobic hydrocarbon biodegradation in deep subsurface oil reservoirs, Carolyn M. Aitken, D. M. Jones & S. R. Larter, Nature volume 431, pages291–294)	The injected CO_2 will impact on microbes.	• The area into which the CO_2 is being injected (>1.5k in depth) historically contains a naturally occurring mix of oil/gas hydrocarbons and other elements and compounds including CO_2 (refer to Chapter 8). • Due to conditions not favourable for microbes, the high temperature and pressure, the low oxygen content, and the fact that no biofilm degradation has been found in the oil refinery indicates that no microorganisms are present in the Moonie anticline. • The liquid CO_2 being injected does not contain microbes. • No adverse impact on microorganisms is expected. • No actions are proposed.	Very Low

The potential of CO_2 leaching into other formations due to geological conditions	CO_2 infused into other aquifers	The potential impact being considered is the release of CO_2 into upper aquifers or other water bodies.	• Given the multiple seals and geological barriers identified by UQ and Bridgeport Energy, the thickness of the seals and the thickness of the transition zones next to the seals between the Precipice and the basal formations and the low permeability in surrounding formations or any identified pathway, the potential for CO_2 to leach out of the oily water leg reservoir and into the immediate zones or to the surface is extremely unlikely. No adverse impact is expected (see Chapters 6,7, & 9). • Greater than 1,500m of vertical geological formation separation exists between the target reservoir and groundwater users. • Monitoring of the injection and production monitoring wells will be ongoing • Given the injection pressure and the porosity and permeability of rock formations, the injected CO_2 has been modelled to remain within the sub surface 40-hectare injection zone. This area is bounded by 5 PM wells which will be continuing their ongoing pumping activity producing a positive fluid drive within the Anticline. • Within the Moonie Field there is an absence of geological structures such as faults and other connecting features in the injection zone that may connect the target formation to overlying groundwater aquifers. • Pearce *et al* 2019 has conducted acid impact studies on Moonie core samples and has concluded that while there may be a reaction with some elements in the transition contact zone of the seals and minor fractures the resultant products are expected to reseal the surface in contact with the weak acid and the acid within the zone will be reduced.	Very Low

Activity	Associated Risk	Potential Impact	Mitigating Control	Residual Risk Rating
			• Low permeability and aquitards preclude any groundwater flow between the Walloon Subgroup and overlying and underlying units, similarly between the Hutton formation and other formations above and below. The evergreen formation sits some 500m below the Hutton formation and then a 30-100m seal to the Precipice formation. Therefore, impacts to water chemistry outside the reservoir will be unlikely. Any impacts would be measured by pressure monitoring long before a water chemistry change is observed.	
Increased reservoir pressure impacts local boreholes	Local farmers can't obtain water and must lower their bore water extraction infrastructure in order to continue to extract water	Local depth of borehole water declines with impact on community.	• Ribeiro *et al* (2019, Evaluating performance of graded proppant injection into a CSG reservoir: a reservoir simulation study, Riberio et al, Unconventional Resources Technology Conference & Proceedings) proposed a model for the injection of 273Mmt of CO_2 into the Surat at CSG levels, predicting a positive impact on local borehole free standing water level. The proposed pilot amendment is only 960,000mTinto a substantially deeper reservoir and as such cannot impact on the levels of water in local boreholes. Hayes et al (2019, the UQ Surat Deep Aquifer Appraisal Project (UQ-SDAAP) Scoping study for material carbon abatement via carbon capture and storage, Supplementary Detailed Report, Regional groundwater model) discussed the effect of salinity and temperature relative to the injection pressure. Bridgeport has used this information to establish the injection pressure range.	Very Low

Activity	Associated Risk	Potential Impact	Mitigating Control	Residual Risk Rating
CO_2 pollutes local bore water used by neighbour	Local neighbours drawing water from the Precipice Formation is impacted by CO_2 in the water	Potential local concern leading to Departmental intervention	• Unlikely, no impact due to low permeability between reservoirs, no connectivity with upper aquifers, the seal transition zone thickness and the fact that locals draw water from shallower better-quality water sands at 50-100m depth. The proposed trial will not adversely impact local users of the Precipice Formation sandstone in the local area as the nearest borehole > one hundred kilometres away. • The target formation is approximately >1,500 m with over 1,400m of vertical separation between the target injection zone and the groundwater users' bores in PL1. • The formation has effectively trapped oil for 90Ma therefore this trap will be just as effective in trapping CO_2 • Highly heterogenous reservoir with limited lateral continuity, three-way dip closure and fault bounded to the west and hence limited connectivity to other formations. See discussion on formation seals.	Very Low

Activity	Associated Risk	Potential Impact	Mitigating Control	Residual Risk Rating
Swapping out old tubulars with new tubulars installation activities,	The mobilization, operation and demobilization of the workover rig could impact on the local environment	Local minor noise or dust generation	Negligible adverse impact. Bridgeport has carried out the drilling of new wells and workovers of existing wells for many years under the existing PL. • The application of usual industry accepted controls and protocols as specified in Chapter 3, the application of the Bridgeport EMP and the Bridgeport Drilling Manual as approved under the existing EA, will eliminate this issue.	Very Low
CO_2 may escape in large volumes through the immediately surrounding oil collection wells or at the production separator	CO_2 escapes through collection well or at the production separator	CO_2 released to atmosphere	• Negligible adverse impact if in small volume, if large volume can have temporary minor impact to local environment and health risk (see Chapter 10 Air). Each well cellar and the production facility will have CO_2 monitoring program which will identify any increase in fugitive CO_2 (>35ppm) and its concentration. This will be used to help determine any changes in the GOR or immediate infrastructure and well operations. If a threshold concentration is reached for some reason then the injection well will be shut down until the impact is nullified.	Very Low

Potential breaching of casing due to overpressure	CO_2 escapes into the atmosphere	The CO_2 could breach through the inner chrome-based tubing or isolating packer and enter the annulus between the casing and the tubing and escape to surface.	• Undertaking pressure logging evaluation and testing of production casing to confirm integrity of production casing and tubing in existing wells, • Continuous production casing pressure monitoring, in particular of the injection well, to ensure no production casing integrity failures and a potential leak path into the surface casing. • Injection pressure limited to below 80% of the tubing and isolation packer yield pressure. The injector well Moonie-27 has 5-1/2" 17 lb/ft J-55 ST&C casing as the production casing, as new it has an API burst yield pressure of 5,320 psi. at 80% the yield pressure will be 29,344 kPag or 4,256 psi. • At the M27 injection well, continuous injection pressure monitoring with upper limit process controls will be in place to stop injection should pressure exceed the specified operating envelope (see Appendix A) 2.0 Incorporation of a high-pressure alarm and trip on the injection pump will -ensure pressure remains below well below tubing/packer casing yield pressure.	Low

CO_2 combining with water to cause acid conditions in the Precipice Formation – main water leg (water aquifer).	Small, localised area of effect	The receiving groundwater quality is adversely changed.	• The Great Artesian Basin including the Precipice Formation aquifer outside the Moonie reservoir, is the size of 130,000 Sydney harbours or 65M GL and the volume of liquid CO_2 injected will be 120,0000 tonnes, or 0.00001 % of the GAB volume. Pearce *et al* (2019) has calculated that the injection of 3m tonnes per annum of CO_2 could reduce the pH to 5.5 over 1,000 years. The volume of this initiation project is proposing to inject over 8 years is 0.09 % of the original volume contemplated by Pearce, therefore having negligible adverse impact. • Local impact is not significant as liquid CO_2 is being injected into the oil reservoir, which already contains oil, water, and other chemicals. • The CO_2 will initiate a number of chemical reactions described in Chapter 8 whereby a mild acid -formed and undergo a reaction with the minerals and carbonates present, effectively trapping resultant products, improving the seal integrity and buffering the pH change (refer to Chapter 8). There will be no adverse impact. • Pearce *et al* (2019) observed that the relatively high reservoir pressure and recharge pressure coupled with high bi-carbonate nature will significantly reduce or nullify the propensity to create acidic conditions away from the bottom hole injection point. • Due to past extraction of oil and water (60MM tonnes) there is a significant volume within the Moonie anticline to accommodate the proposed injection of 120,000 tonnes CO_2, with only 15% of the potential pore volume being displaced in the reservoir over the eight years of injection of this initial project. • No mitigation methods are proposed other than monitoring	Very Low

Impact of CO_2 on microbes	Anaerobic hydrocarbon degradation is a common process in biodegraded subsurface oil reservoirs, the presence of more acidic conditions may reduce this adverse impact, (Aitken et al 2004, Anaerobic hydrocarbon biodegradation in deep subsurface oil reservoirs, Carolyn M. Aitken, D. M. Jones & S. R. Larter, Nature volume 431, pages291–294)	The injected CO_2 will impact on microbes.	• The area into which the CO_2 is being injected (>1.5k in depth) historically contains a naturally occurring mix of oil/gas hydrocarbons and other elements and compounds including CO_2 (refer to Chapter 8). • Due to conditions not favourable for microbes, the high temperature and pressure, the low oxygen content, and the fact that no biofilm degradation has been found in the oil refinery indicates that no microorganisms are present in the Moonie anticline. • The liquid CO_2 being injected does not contain microbes. • No adverse impact on microorganisms is expected. 3.0 No actions are proposed.	Very Low

The potential of CO_2 leaching into other formations due to geological conditions	CO_2 infused into other aquifers	The potential impact being considered is the release of CO_2 into upper aquifers or other water bodies.	• Given the multiple seals and geological barriers identified by UQ and Bridgeport Energy, the thickness of the seals and the thickness of the transition zones next to the seals between the Precipice and the basal formations and the low permeability in surrounding formations or any identified pathway, the potential for CO_2 to leach out of the oily water leg reservoir and into the immediate zones or to the surface is extremely unlikely. No adverse impact is expected (see Chapters 6,7, & 9). • Greater than 1,500m of vertical geological formation separation exists between the target reservoir and groundwater users. • Monitoring of the injection and production monitoring wells will be ongoing • Given the injection pressure and the porosity and permeability of rock formations, the injected CO_2 has been modelled to remain within the sub surface 40-hectare injection zone. This area is bounded by 5 PM wells which will be continuing their ongoing pumping activity producing a positive fluid drive within the Anticline. • Within the Moonie Field there is an absence of geological structures such as faults and other connecting features in the injection zone that may connect the target formation to overlying groundwater aquifers. • Pearce *et al* 2019 has conducted acid impact studies on Moonie core samples and has concluded that while there may be a reaction with some elements in the transition contact zone of the seals and minor fractures the resultant products are expected to reseal the surface in contact with the weak acid and the acid within the zone will be reduced.	Very Low

			Low permeability and aquitards preclude any groundwater flow between the Walloon Subgroup and overlying and underlying units, similarly between the Hutton formation and other formations above and below. The evergreen formation sits some 500m below the Hutton formation and then a 30-100m seal to the Precipice formation. Therefore, impacts to water chemistry outside the reservoir will be unlikely. Any impacts would be measured by pressure monitoring long before a water chemistry change is observed.	
Increased reservoir pressure impacts local boreholes	Local farmers can't obtain water and must lower their bore water extraction infrastructure in order to continue to extract water	Local depth of borehole water declines with impact on community.	Ribeiro *et al* (2019, Evaluating performance of graded proppant injection into a CSG reservoir: a reservoir simulation study, Riberio et al, Unconventional Resources Technology Conference & Proceedings) proposed a model for the injection of 273Mmt of CO_2 into the Surat at CSG levels, predicting a positive impact on local borehole free standing water level. The proposed pilot amendment is only 960,000mTinto a substantially deeper reservoir and as such cannot impact on the levels of water in local boreholes. Hayes et al (2019, the UQ Surat Deep Aquifer Appraisal Project (UQ-SDAAP) Scoping study for material carbon abatement via carbon capture and storage, Supplementary Detailed Report, Regional groundwater model) discussed the effect of salinity and temperature relative to the injection pressure. Bridgeport has used this information to establish the injection pressure range.	Very Low

CO_2 pollutes local bore water used by neighbour	Local neighbours drawing water from the Precipice Formation is impacted by CO_2 in the water	Potential local concern leading to Departmental intervention	• Unlikely, no impact due to low permeability between reservoirs, no connectivity with upper aquifers, the seal transition zone thickness and the fact that locals draw water from shallower better-quality water sands at 50-100m depth. The proposed trial will not adversely impact local users of the Precipice Formation sandstone in the local area as the nearest borehole > one hundred kilometres away. • The target formation is approximately >1,500 m with over 1,400m of vertical separation between the target injection zone and the groundwater users' bores in PL1. • The formation has effectively trapped oil for 90Ma therefore this trap will be just as effective in trapping CO_2 • Highly heterogenous reservoir with limited lateral continuity, three-way dip closure and fault bounded to the west and hence limited connectivity to other formations. See discussion on formation seals.	Very Low

Swapping out old tubulars with new tubulars installation activities,	The mobilization, operation and demobilization of the workover rig could impact on the local environment	Local minor noise or dust generation	Negligible adverse impact. Bridgeport has carried out the drilling of new wells and workovers of existing wells for many years under the existing PL. The application of usual industry accepted controls and protocols as specified in Chapter 3, the application of the Bridgeport EMP and the Bridgeport Drilling Manual as approved under the existing EA, will eliminate this issue.	Very Low
CO_2 may escape in large volumes through the immediately surrounding oil collection wells or at the production separator	CO_2 escapes through collection well or at the production separator	CO_2 released to atmosphere	Negligible adverse impact if in small volume, if large volume can have temporary minor impact to local environment and health risk (see Chapter 10 Air). Each well cellar and the production facility will have CO_2 monitoring program which will identify any increase in fugitive CO_2 (>35ppm) and its concentration. This will be used to help determine any changes in the GOR or immediate infrastructure and well operations. If a threshold concentration is reached for some reason then the injection well will be shut down until the impact is nullified.	Very Low

12.8 Data Acquisition and Monitoring

Monitoring of the project area boreholes, the production/monitoring wells and outer production wells will be used to gather reservoir pressure, CO_2 and oil concentration and water quality characteristics to validate the CO_2 reservoir model and project controls and determine any changes in the designed Gas Oil ratio (GOR) thresholds and well operations.

The first step will be to create and validate a background database of the various formation parameters to compare with ongoing data to determine any changes, and to validate the speed and direction of the miscible flood front through the target formation to the PM wells.

The following water quality parameters will be considered for use as part of the monitoring plan key performance indicators (detailed in the Chapter 4 Monitoring Plan),

- The reservoir pressures,
- Produced water pH concentration and ion concentrations in addition to current quarterly monitoring,
- Produced water Ion concentrations, and
- CO_2 concentration and the Gas to Oil Ratio at the production facility together with and

Water characteristics currently being monitored and reported.

12.8.1 Trend Analysis – Data and Threshold Values

All the water analysis will be completed by a NATA accredited laboratory and will be used to determine threshold values compared to the current water quality survey. Besides quarterly sampling as presently undertaken, if further periodic sampling is needed it will be undertaken to determine if there is any change.

12.9 Exceedance Response Plans

If any well exceeds the pressure parameters or produced water quality thresholds measured at the evaporation ponds exceed parameters, depending on the exceedance, action will be taken.

- For low level exceedance: the exceedance will be assessed as to the probable cause and adjustments to the process made until the process is within specifications,
- For high level exceedance: production will stop, and further assessments and checks will be undertaken. A number of contingency plans (refer to Chapter 3, and section 3-20) have been identified and they will be employed where required.
- For continued exceedance not controlled by the contingency plans or other interventions then the project will be suspended while detailed testing and analysis occurs.

12.10 Assessment of environmental impacts: Groundwater

Given the results of studies and reservoir models that have been completed and the groundwater management plans detailed in10-1, no significant adverse environmental impact from the initial CO_2 injection project is envisaged. If any of the field monitoring parameters are exceeded, they will be investigated and will trigger the contingency plans detailed in Chapter 3.

12.11 Precipice Main Reservoir Statistics

The Precipice aquifer reservoir pressure qualities are listed below in the Appendix A.

Appendix A: Groundwater Pressure Data Table 12-1

Moonie Oil Reservoir Statistics, at a Glance.					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Reservoir Stats					
Original Precipice Oily Water Leg Reservoir Pressure (1,515m)	17,450	2,530			
Current Precipice Oily Water Leg Reservoir Pressure (1,515m)	16,550	2,400			
Formation Slip Pressure					
Slip Pressure (P90=53,150kpa, mean 57,250 kPa)	51,700	7,498			
Formation Seals					
Seal thickness					20-100
Reservoir Fracture Seal Pressure	52,170	7,565			
Permeability - ultimate seal core plugs			0.003 - 0.086 av 0.037		
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,808			
Bottom Hole Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,711			
Permeability					
Bulk Permeability Precipice main water leg Horizontal, mean			580		
Precipice main water leg Horizontal, mean			127		
Ultimate Seal			0.003 - 0.086 av 0.037		
Pore Throat measurements					
Precipice M38					0.01 - 100 µm

Moonie Oil Reservoir Statistics, at a Glance.					
Item	**kPa**	**psi**	**mD**	**%**	**m**
Porosity					
Evergreen				13	
Precipice Main reservoir (average Sandstone)				16.8	
Injection Pressure Thresholds					
Gravity Head of the injecting fluid ($scCO_2$) - density of $480kg/m^3$	7,172	1,040			
Friction Loss of injecting	689	100			
Maximum Allowable injection Pressure (90% of the minimum Fracture pressure)	46,953	6,809			
Maximum Allowable Fracture Pressure thermally adjusted 14.5% of Max allowable pressure above	39,388	5,712			
Miscibility * depends on temperature $scCO_2$ pressure range	>17,000	>2,465			
Estimated Injection pressure range, depends on temperature, mass, density	>17,000	>2,465			
Recommended Pressure Alarm Settings					
WHP High Pressure Alarm setting, *subject to design calculations	39,388	5,712			

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13.0 Executive Summary

The oil field injection zone within the Precipice formation “oily water leg” reservoir sitting above the main Precipice formation “main water leg” reservoir and confined by a geological anticline, has been assessed as having no significant impact to the receiving environment, due to:

- The existing disturbed condition of the receiving environment groundwater (the Precipice formation “oily water leg” reservoir) as it has been pumped since 1964 (refer to Chapters 7,8 & 12),

- From an environmental perspective, the Precipice formation reservoir “oily water leg” within the Moonie Anticline has water, oil, oil fractions, and related organic compounds and is unfit for surface use unless treated to ANZACC standards,

- There is no evidence of microbial activity due to:
    - The current chemical condition, temperature and depth of the formation which precludes microbial life,
    - The reservoir pressure is ≥ 2,300 psi at 1.766 km,
    - The oxygen level is severely depleted and shows evidence of ancient scavenging being O^2 <0.3mg/L,
    - No light at 1.6km,
    - No biological biofilm has been detected at the oil refinery.

- Liquid CO_2 injection process (-20C, 330psi) cannot introduce microbes to the formation,

- Given the results of studies and reservoir models that have been completed and the groundwater management plans detailed in this amendment, no significant environmental harm to the receiving environment is expected,

- If any of the field monitoring parameters or thresholds are exceeded, they will be investigated and if conclusive then the contingency plans detailed in Chapter 3 will commence. If a high-risk event occurs, the field will be shut in and the project reassessed, the injection process will stop until risk mitigation measures are put in place to rectify (see Chapter 3: Contingency Methods).

13.1 Introduction

The changes to the oil reservoir have been modelled and localised changes to water quality within the Precipice formation reservoir “oily water leg” are expected, however these changes are not forecast to have a significant impact to the receiving environment.

The receiving environmental aspects include,

- Stygofauna unlikely to be found below 100m, or in hypoxic groundwater (Stygofauna in Australian Groundwater Systems: Extent of Knowledge: Report to the Australian Coal Association Research Program (ACARP) Hose et al (15 July 2015) CSIRO Land & Water Division & Macquarie University).

- Microbes not detected in the oily water and evidence of microbial decomposition and degradation of oil not found in the oily water extract,

- Low O^2 (<0.3mg/L), oxygen has been used up by previous ancient activity and is scarce,

- Natural CO_2 present (5 mol % CO_2) from ancient thermo-intrusive events,

- Temperature in the water column being 60 - 80$^oC^+$,

- Groundwater pH 8.4,

- TDS varies up to 1,800 mg/L,

- Average greater reservoir pressure is 2,330 psi at 1.766 km,

- Solution Gas Oil Ratio of Moonie crude oil, 270 scf/bbl, with an API Gravity of 43-45^o (classified as light oil),

- High sodium absorption ratio, the actual SAR is between 120 to 220,

- Reservoir carbonates levels of 1,362mg/L are (high in comparison to potable water) and free bicarbonates at 760 mg/L,

- Full range of hydrocarbons which are toxic to microbes,

- Receiving environment is sterile, can be > 80°C, pH 6.5 – 5.5 (following injection),

- The Precipice formation "oily water leg" reservoir pressure of 2,198 psi at 1,700m (slightly lower than initial main reservoir pressure at field discovery due to drawdown from artificial lift on wells),

- No evidence from the refinery as to oil quality degradation or presence of any organic material (biofilms) that would suggest the presence of microbes and trigger microbial investigation,

- No evidence from oil fields of tell-tale signs of microbial activity (excessive H_2S gas or organic biofilms),

- Existing "disturbed water" characteristic of the receiving environment conditions by the removal of 67.6Mt of water and oil since 1964,

- Evidence of previous natural CO_2 and hydrothermal fluid alteration i.e., the creation and migration of oil and gas from lower formations being trapped in the anticline, fractured quartz grains, and fracture fills has been observed to occur, with mineral trapping as carbonates in core samples throughout the Surat Basin,

- Anticlinal fault bounded geological structure precludes ingress of new microbes, the oil, water and gas, carbonates and minerals have aggregated in the anticline and in place for 90 Ma,

- Downhole, original microbes which produced some of the oil and gas have long been extinct.

- No evidence of in place oil degradation, conditions preclude presence of active microbes,

- There is evidence of original population presence in the form of prehistoric dinoflagellate exoskeletons (silica base), and also extensive fossilised microbes in core samples,

- Existing wells are sub-artesian and under pressured not able to deliver water to surface on existing pressure (i.e., to receive the oil and water at the surface requires pumping.

13.2 Water Quality Before and After CO_2 Injection

Table 13-1 below, contrasts the water quality of the receiving environment before and after the CO_2 injection.

Table 13-1, Assessment of Impact on water quality aspects

Existing downhole water quality and characteristics	Conditions following Injection
O_2 Low (<0.3mg/L)	O_2 will remain low
Temperature in the water column from 60 to >80+°C	Temperature will return to equilibrium within the reservoir over time
Severely disturbed water receiving environment caused by the removal of Mtn water and oil, (67.6MMt extracted)	Water condition will remain disturbed with mixed liquid CO_2.
Groundwater pH 8.4	The modelling predicts pH will change within the oily water leg going to pH 5-6 (4-5 using the larger volume 3MMt U of Q injection model), however post injection, over time the pH will return to the average reservoir pH.
TDS varies up to 1,800 mg/L,	No additional solids introduced; no change expected
Reservoir water high in carbonates 1,362 mg/L , free bicarbonates at 760 mg/L (high in comparison to potable water)	Carbonate presence will buffer mild acid reaction chemically trapping CO^2 ions, see Chapter 8: Geochemistry
Full range of hydrocarbons and related organic compounds.	Remain similar, however availability for extraction will reduce over time.
Sterile receiving environment	No microbes will be introduced and conditions for the enhancement of microbial life will not change, the receiving environment will remain sterile

Existing downhole water quality and characteristics	Conditions following Injection
No evidence from refinery as to oil quality degradation or presence of any organic material that would trigger microbial investigation	No microbes will be introduced by the injection of CO_2
No evidence from oil fields of tell-tale signs of microbial activity (gas H_2S or organic biofilms)	No change expected continuing with ongoing monitoring
Reservoir Pressure	Modelling has indicated that no long-term change is expected, continuing with monitoring. Reservoir modelling forecasts that on conclusion of pumping and abandonment of the field the reservoir pressure will return to reservoir conditions close to original.

13.3 Formation of Convection Currents

The potential for the formation of localised convection currents due to temperature fluctuation is nil due to the relatively low vertical permeability (as compared to horizontal permeability), laminar nature and strength of the formation, as is evidenced in the core samples tested by UQ, and dynamic flow conditions during injection and production operations.

CO_2 will be injected at pressure to permeate the formation; the CO_2 remains in a critical state in the oily water leg and reacts miscibly with the oil. While there will be infusion of CO_2 into the rock formation and fluids of the oily water leg, there will be no creation of “currents”, as such, due to the preferential horizontal permeability within the formation and dynamic flow from the injector towards the lower pressure production wells.

13.4 Precipice Formation Reservoir - pH

With this initial project the localised pH reduction is towards neutral and is not expected to precipitate heavy metals as the pH change is toward a neutral state where the minerals and metals are not precipitated but held in solution. Three chemical trapping mechanisms will be operating within the Precipice oily water leg, and this is discussed in Chapter 8 Groundwater Geochemistry.

Predicted dissolution of carbonates and feldspar is consistent with observations from experiments using relative permeability reactions performed as part of the UQ-SDAAP and other projects.

Precipitation of kaolinite, ankerite and smectite has been observed where there has been natural ancient CO_2 induced alteration.

13.5 Effect of Injection - Temperature

Injected CO_2 must be above 31.1°C and a liquid to facilitate the development of a miscible flood front to sweep oil and avoid the occlusion of pore spaces within the Precipice reservoir formation.

UQ predict temperature change within and restricted to the immediate contact area of the injection zone, in time the temperature will return to the original temperature and dependant on the heat of the CO_2 when it is at the injection sand face due to thermal induction.

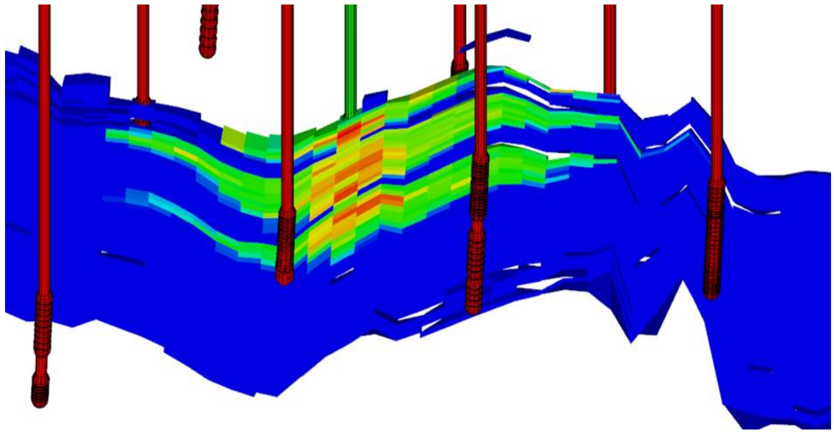
On injection the liquid CO_2 in contact with the reservoir fluid (water and oil), some will mix/dissolve due to its solubility. Interactions between CO_2 and oil can change the properties of the exposed trapped oil, such that the oil swells slightly and its viscosity is reduced, resulting in more oil being mobilized and swept to a producing well (miscible flood process).

13.6 CO_2 Flood Front development over time

The immediate development of a CO_2 flood front and its extension into the rock formation will be controlled by the governed injection volume, pressure from the injection pump located on the surface, temperature and miscibility of the injected fluid. The pressure at surrounding wells will be closely monitored along with the produced “Gas to Oil” ratio (GOR) at the five production wells and the analyses of the actual constituents of the produced oil water sampling undertaken at the evaporation ponds, including pH, ions and CO_2 concentrations as illustrated above.

Figure 13-1 overpage: Illustrates the development of the CO_2 flood front extending from the injection well towards the five-surrounding monitoring/production wells at 12 months.

Figure 13-1, 3D illustration of $scCO_2$ cloud at 12 months



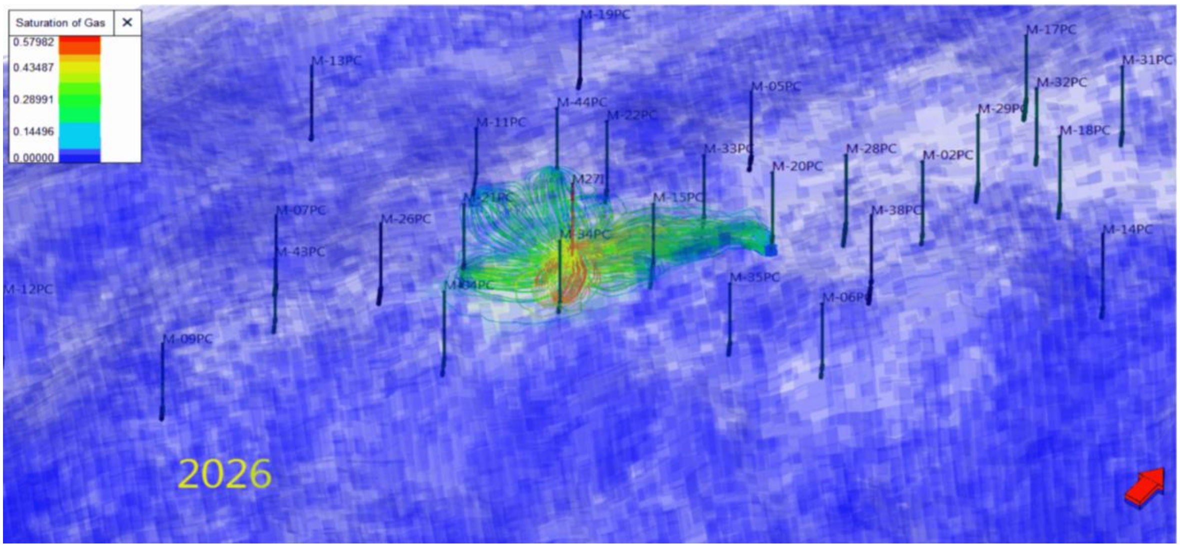
M27 Injection Well (green)

Monitoring wells in Red

13.7 The predictions from the Dynamic Model

The dynamic model forecasts the rate of movement of the CO_2 flood front through the formation. The 2D volumetric expansion and contraction of the CO_2 cloud over a 21-year period is illustrated in Figures 13-2 to 13-5 below. The flood front first expands out to the production wells and then over time contracts post injection.

Figure 13-2, The 2D Volumetric extent of CO_2 flood front at year 3 (2026)



Red, yellow and green depict declining saturated gas levels

Figure 13-3: A Plot of the Pilot Simulated CO_2 flood front 24 months after injection.

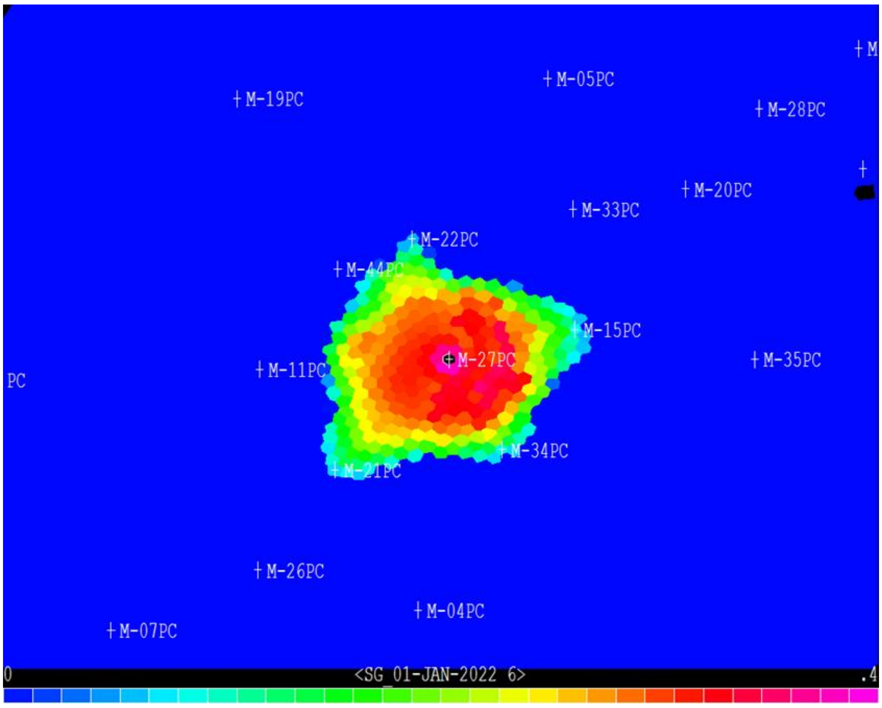
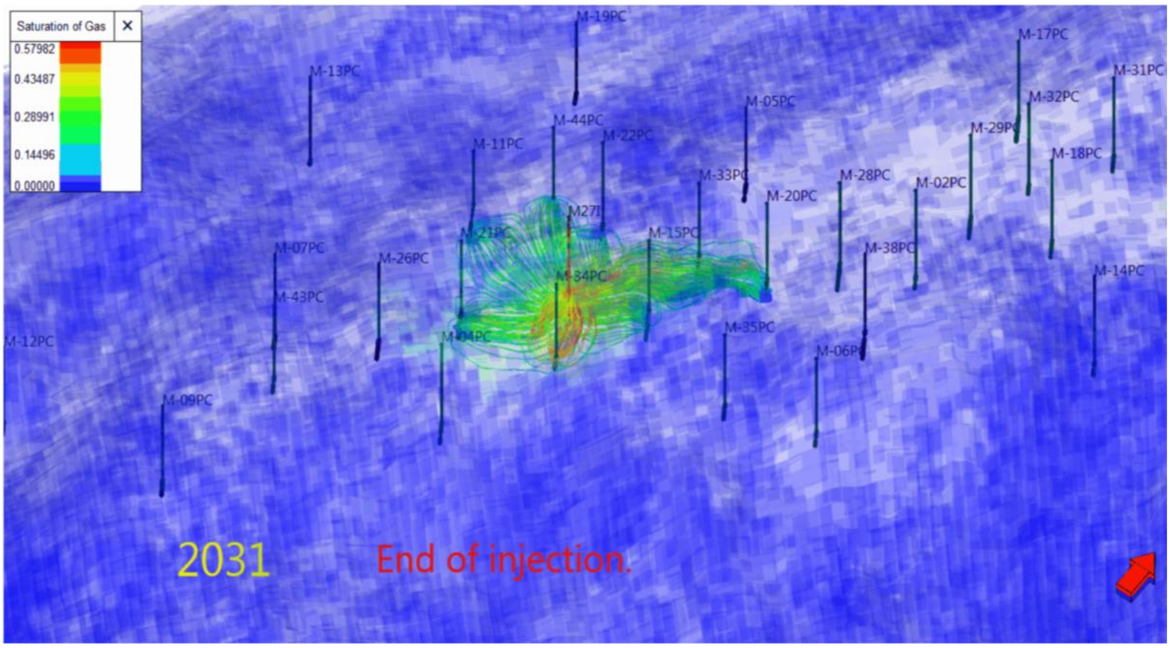
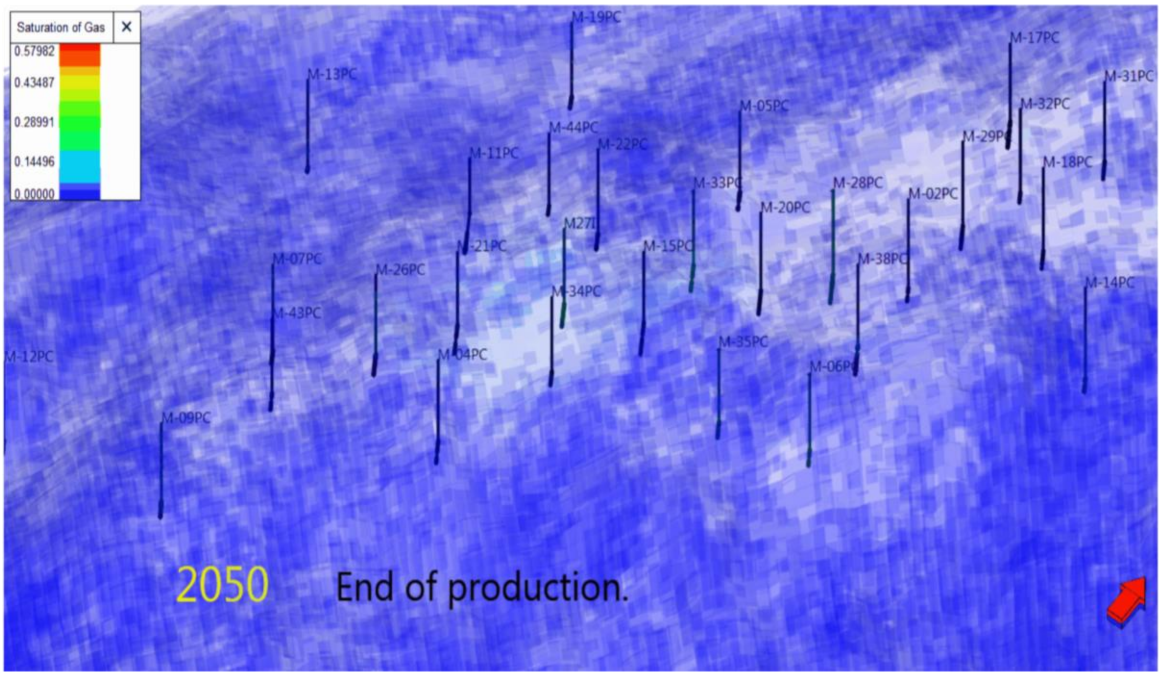


Figure 13-4, The 2D Volumetric extent of the CO_2 flood front at Year 9 (2031) End of Injection



Red, yellow and green depict declining saturated gas levels

Figure 13-5, The 2D Volumetric extent of the CO_2 flood front at 2050 (End of Full Field Production)



Red, yellow and green depict declining saturated gas levels

13.8 3D Volume Injection Models

The 3D model prediction of CO_2 saturation within the Moonie Oil formation over time

Figures 12-6, 12-7, and 12-8 below, illustrates in 3D the saturation of CO_2 within the Precipice formation “oily water leg” reservoir over time.

Figure 13-6, The 3D saturation of CO_2 at year 3 (2026)

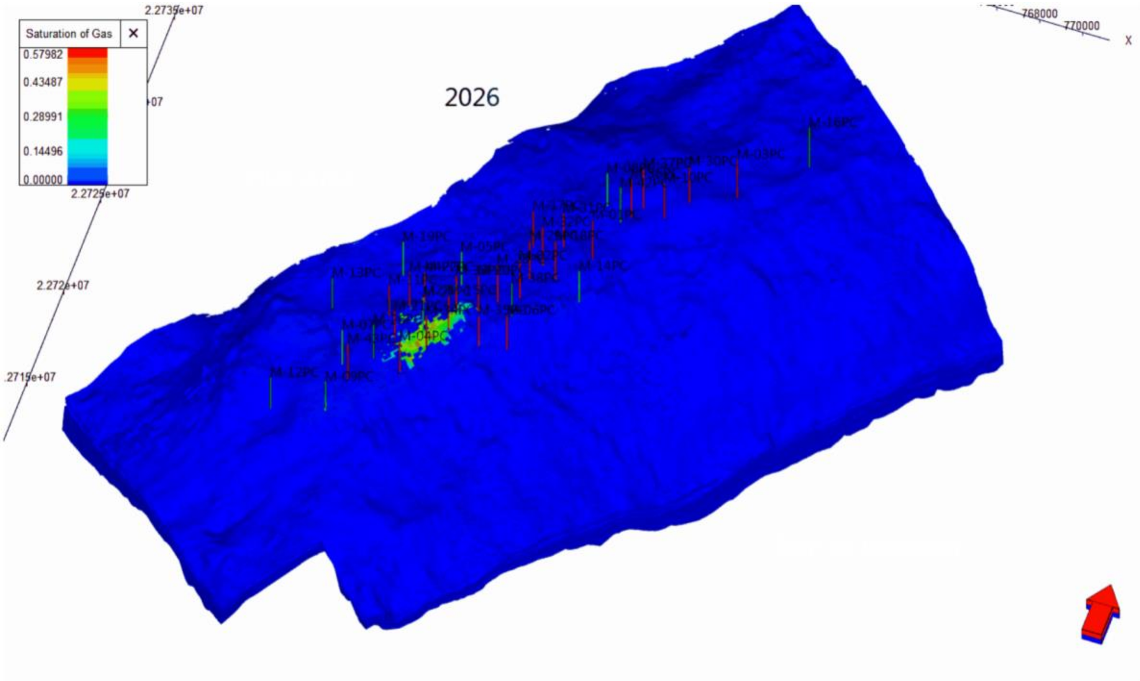


Figure 13-7, The 3D saturation of CO_2 at year 9 (2031) End of Injection

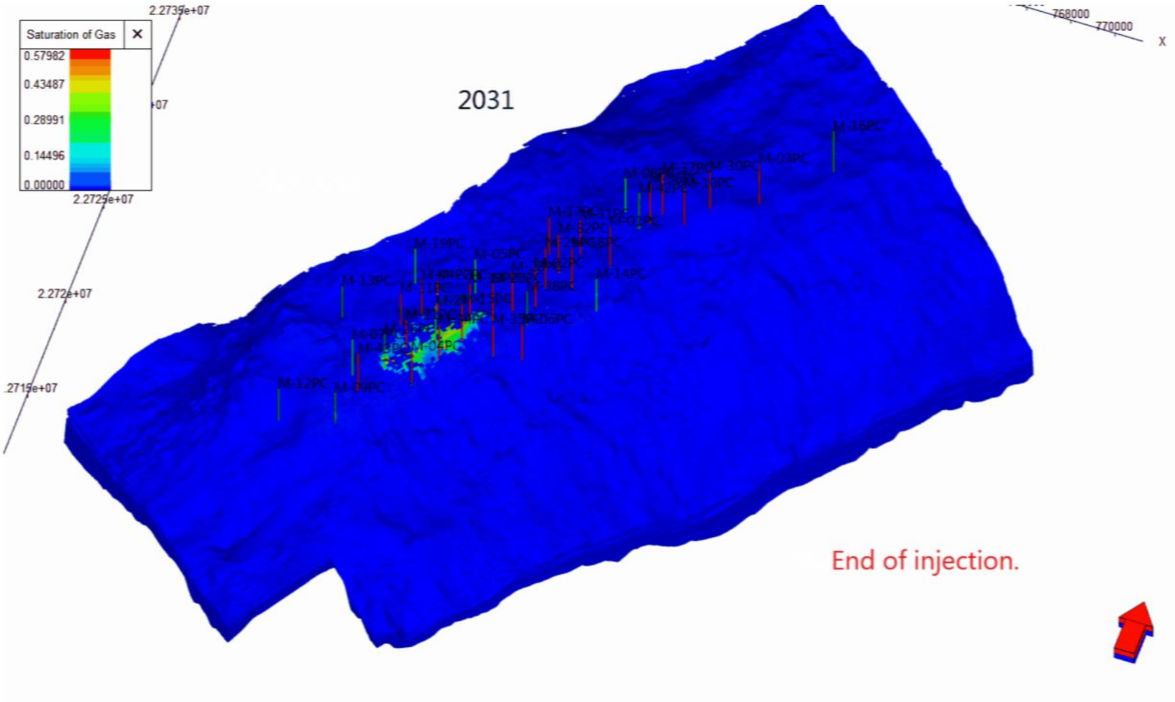
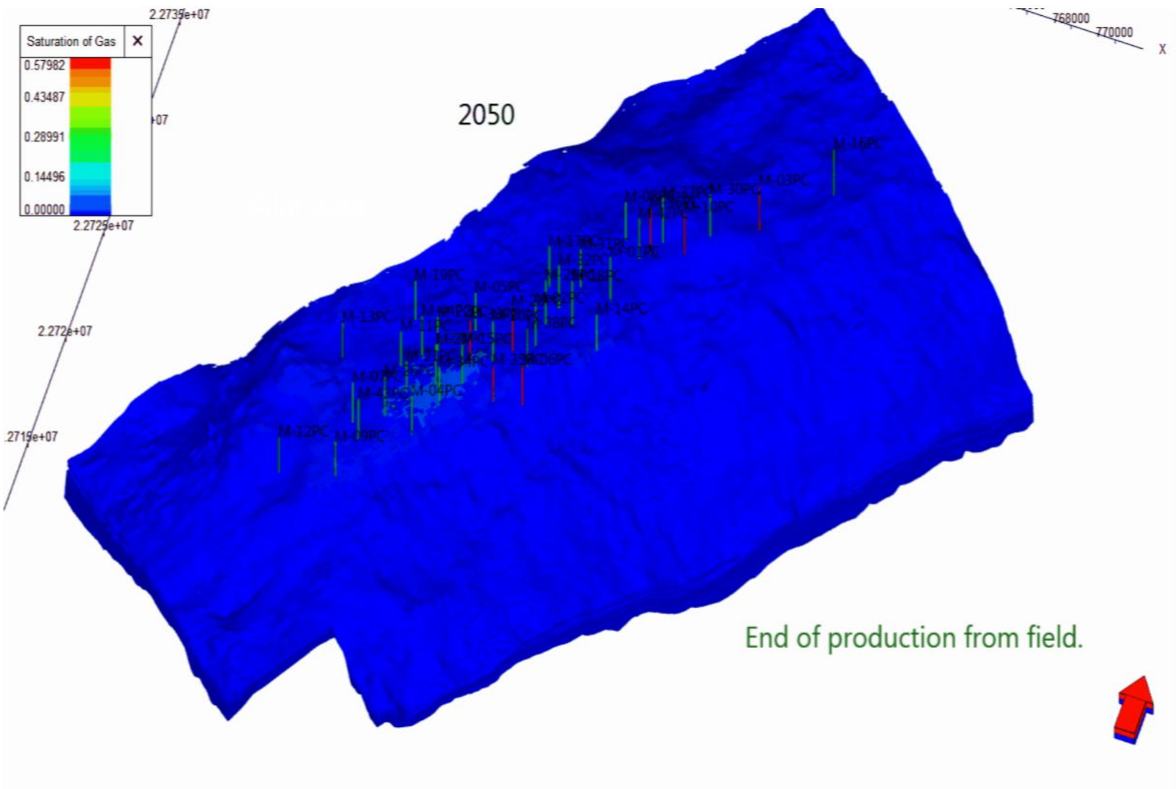


Figure 13-8, The 3D saturation of CO2 at year 21 (2050) post injection (End of Full Field Production).



13.9 2D Vertical section through the Moonie Oil Field illustrating CO_2 saturation over time

The following three Figures illustrate the CO_2 flood front at 3 years (2026), at the end of the injection period in 2031 and at the end of production 2050. The figures also illustrate the position of the initial oil water contact in 1963. The CO_2 flood front remains considerably higher than this interface throughout the project.

Figure 13-9, 2D Vertical section through the Moonie Oil Field depicting flood front position at year 3 (2026)

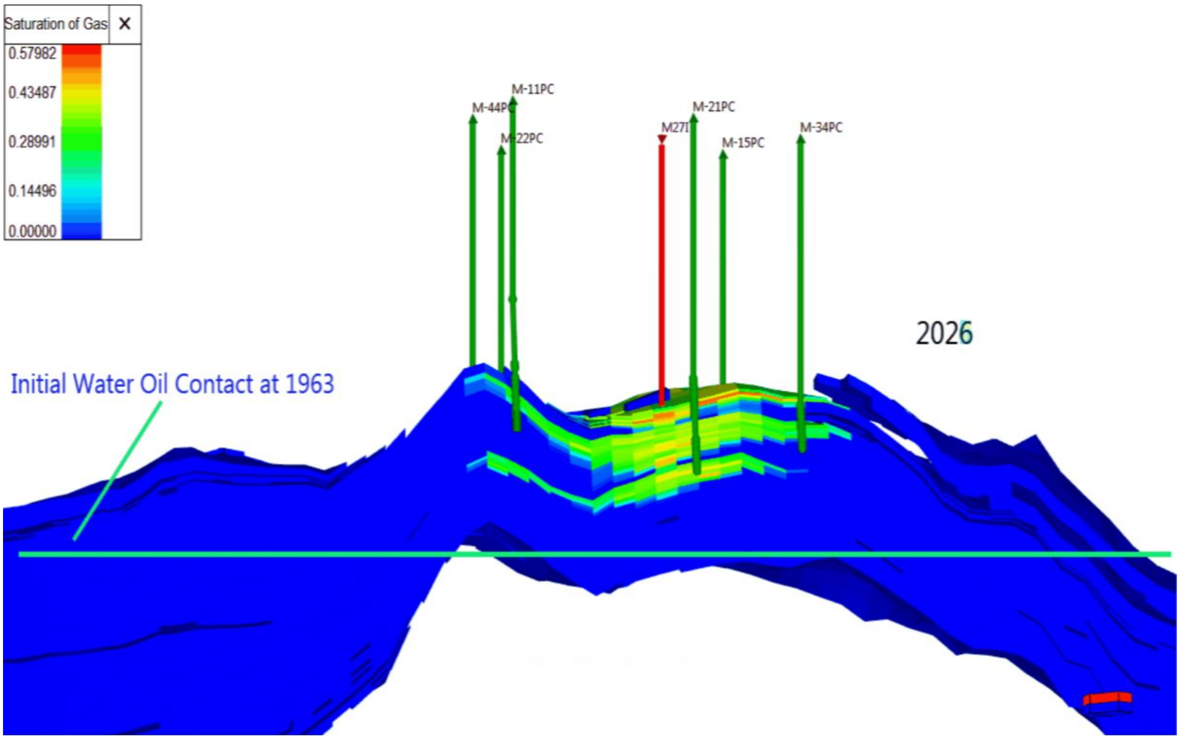


Figure 13-10, 2D Vertical section through the Moonie Oil Field depicting flood front position at end of injection (2031)

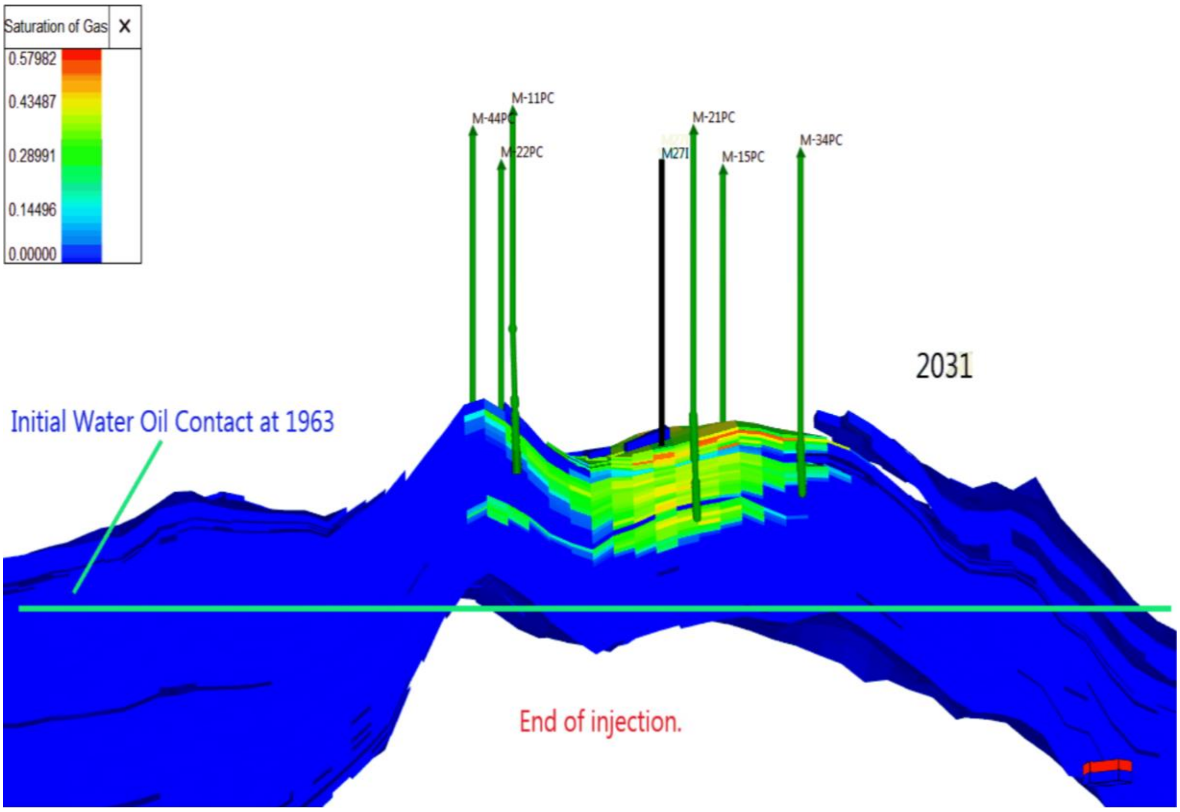
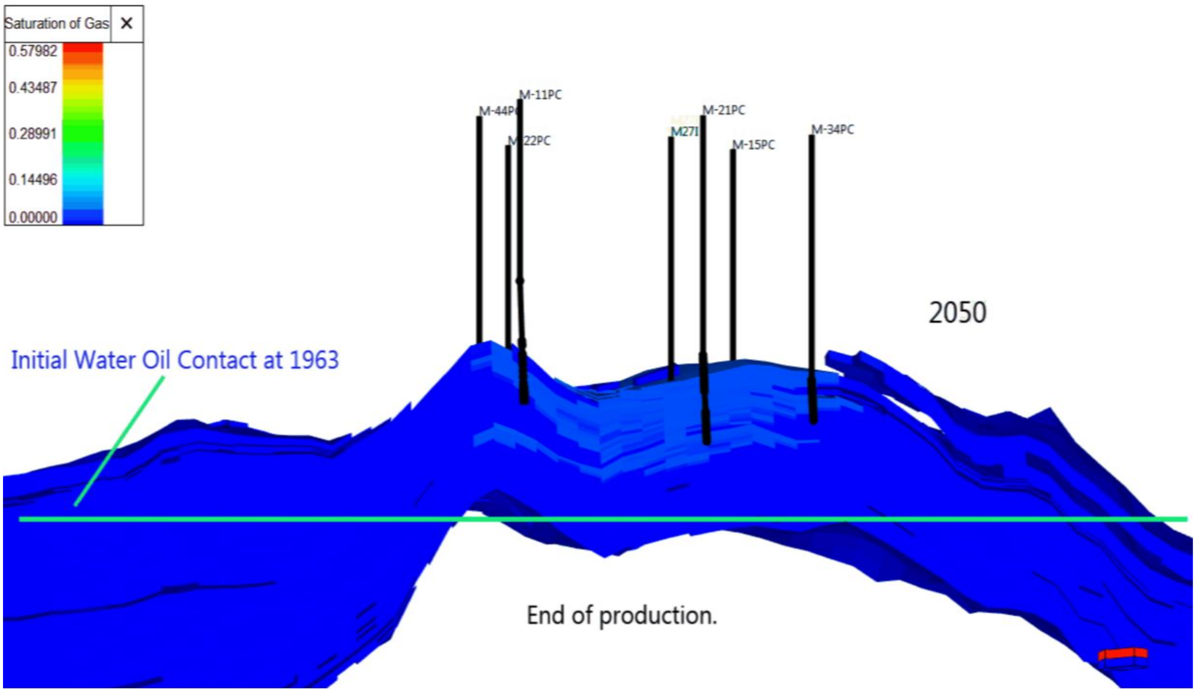


Figure 13-11, 2D Vertical section through the Moonie Oil Field depicting flood front position at end of full field production (2050)



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Chapter 14: Assessment of Impact: Operations

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14.0 Summary

The purpose of this chapter is to review the site CO_2 operations and make an environmental assessment of potential impacts of site operations and then propose mitigating actions to control the impact to ALARP and Best Industry Practice.

The Site Operations assessed include:

1. Delivery of the CO_2 to site,
2. Storage of CO_2 at site,
3. Surface adjustment of the liquid CO_2 state prior (potential preheat) to injection,
4. The CO_2 injection and pumping process,
5. Operation of the production/monitoring (PM) wells,
6. The surface oil and gas separation and future recycling, and
7. Monitoring on the PM wells as detailed in Chapter 5.

Bridgeport's "Operations team" will prepare the scope, the basis of design, and the detailed design process, which will include risk assessment workshops and the preparation of operation and equipment maintenance procedures. All of this will be applied under the existing environmental management plan (EMP) and under the existing safety management system (SMS) and in accordance with Bridgeport authorised policies. This will see the continuing use of the site Job Safety Analysis (JSA) and Safe Operating Procedure (SOP) prior to all operational tasks being implemented.

14.1 Introduction

This is an assessment of CO_2 Operations during delivery, storage, injection and monitoring operational activities.

14.1.1 CO_2 Delivery to Site.

In this initial CO_2 project, the CO_2 will be delivered by truck, using existing industry certified ISO liquid CO_2 containers on transport trucks. Later projects with higher volumes will anticipate the use of a dedicated pipeline from Milmerran to the Moonie field.

14.1.1.1 Assessment of environmental impacts: CO_2 Delivery

If CO_2 is released to the atmosphere during the delivery process, depending on the amount, negligible impact will occur as the CO_2 will dissipate immediately. A safety zone will be determined during the design phase by considering the project risk assessment, and industry specifications. For example, an initial safety zone of 3m from the injection well CO_2 infrastructure will be established, signposted and regular monitoring of gas levels in and around the injection site will be undertaken. Safe workplace thresholds for gaseousCO_2 being used will be at levels of CO_2 concentration greater than 35ppm within the working envelope and will preclude any ongoing work without breathing apparatus. As minor levels of hydrogen sulphide are present in the injection fluid stream the workplace exposure limit threshold will similarly be set at levels consistent with industry standards, e.g., within the 3m working envelope of the well and in the PM well cellars.

A windsock and signposted muster points will be mounted in the vicinity of CO_2 surface injection operations.

14.1.2 CO2 Storage

The liquid cooled CO_2 will be stored in an appropriate industrial certified liquid CO_2 storage vessel. This vessel will have a venting mechanism for emergency release, with the actual vent discharging away from the facility via the onsite flare tower or with its own dedicated vertical vent.

14.1.2.1 Assessment of environmental impacts: CO_2 Storage

If the Bridgeport storage process and procedure utilising standard practices for handling liquid CO_2 are implemented, no CO_2 will be directly released to the atmosphere during the storage process.

14.1.3 CO_2 Injection

The liquid CO_2 will be pumped from the storage tank via a small heat exchanger (subject to detailed design requirements) to slightly warm the CO_2 prior to surface injection into the M27 injection well. The heat exchanger warms the liquid CO_2 to the ideal temperature for injecting downhole into the formation. The liquid CO_2 is injected by cryogenic high pressure liquid CO_2 pumps. The heat and pressure at surface is in part governed by the tubing and wellhead material strengths and in part by the desired bottom hole pressure and temperature to minimise impact at the sandface and ensure the CO_2 is close to supercritical when it enters the reservoir.

14.1.3.1 Assessment of environmental impacts: CO_2 Injection

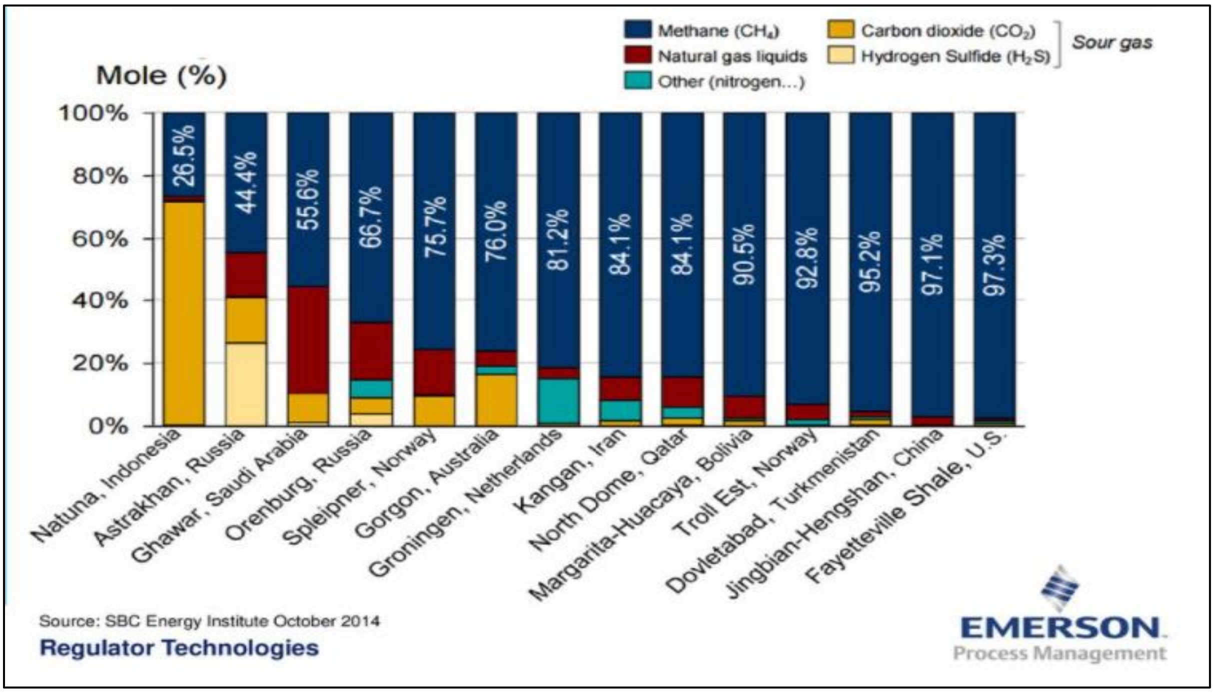
CO_2 forms 3.14-4 % of the Earth's atmosphere. The release of trace amounts of CO_2 will have no significant environmental impact, however, a safety zone subject to design, for example, of 3m around the infrastructure and regular gas leak detection surveys to ensure the detection of any leaking gas, together with an emergency vent system will be instigated.

14.1.3.2 Carbon Dioxide Injection Well Blowout

Bridgeport has no history of a blow-out on any exploration or production well, and all Moonie wells will be managed as per the Bridgeport well integrity management system (WIMS), which honours the QLD Code of Practice.

A CO_2 injection well blow out is an incident where the CO_2 injection well fails, and CO_2 is liberated at the well head under high pressure. A well blowout is an inherent risk for all petroleum wells, and it is safely managed by established design processes and the selection of material based upon industry standards and regulatory requirements. High CO_2 content is not unique in the petroleum industry and there are many large gas projects throughout the world that competently manage these fluids. Some of these large projects are presented in Table 14.1 below.

Figure 14.1 Worldwide LNG projects with the % of CO_2 produced



14.1.3.3 Volume of CO_2 injection is insufficient to cause overpressure.

It is important to note that at no point is it possible to overpressure the currently depleted under pressure reservoir during this initial stage project using the specified injection pressures (Chapter 3) and simply because the rate and volume of CO_2 injection is insufficient to cause overpressure conditions at either the Injection well or the Production Monitoring wells. The PM wells in particular by virtue of producing with the artificial lift installed, act as a reservoir pressure sink at the offtake points. This design feature of the project alone ensures there is no possibility of locked or trapped pressure events in the reservoir. This does not mean that BEL will be complacent, and it will continue to apply its standards and procedures via its authorised WIMS through monitoring the production casing annuli on all its wells, a standard it already undertakes.

14.1.3.4 Corrosion Management, Monitoring and Corrosion Coupons.

The additional well control risk introduced by CO_2 is the potential risk of corrosion. The CO_2 corrosion rate of steel is dependent upon the chemistry of the received fluids (discussed in Chapter 8) and the partial pressure of CO_2. For the producing wells the bottom hole flowing pressures (500 – 1,000psi) are very low due to the artificial pumps being utilised so there is negligible CO_2 corrosion at the existing CO_2 content of 5%. During the project the CO_2 content in the producing wells will need to increase by several multiples before the corrosion rate becomes a concern.

At the wellhead, where an integrity breach could result in a surface blow-out, much higher percentages of CO_2 are required to become corrosive, as the flowing pressures are even lower than the flowing bottom hole pressures (100 – 200 psi). The producing wells will be monitored for CO_2 percentage and the level of pH and shut-in and reassessed when they reach 15% CO_2 concentration, or a consistent pH concentration considered to precipitate excessive corrosion. In any event corrosion coupons will be inserted in the wellheads and surface flow lines and monitored on a regular basis. Excessive corrosion will trigger the shut-in process and subsequent upgrades. The well will then be worked over to replace any steel components that are wetted by produced fluids with corrosion resistant components prior to placing the well back onto production.

Any shut-in or suspended (temporarily abandoned) wells in the field will be monitored for changes in pressure as per the Bridgeport WIMS. If a material pressure change is detected, it will be investigated, and contingency plans activated to mitigate the risk and re-instate the well's integrity so it's acceptable to the WIMS and the Code of Practice.

It is noted from available public information, that in 2011 a major release of CO_2 occurred at the Tinsley Field which was operated by Denbury Resources. It was reported as a “well blowout” when it was actually caused by an excavator accidently digging up the 8” CO_2 injection pipeline owned by the CO_2 delivery company. Bridgeport will avoid a similar incident by designing and installing any pipelines in designated pipeline corridors which are clearly marked, and sign posted as per Australia standards for pipelines and the Bridgeport Pipeline Integrity Management Plan. Also, isolation valves will be installed at CO_2 storage tanks, injection lines and on the wellhead and an isolation valve (DHSV) or XN profile for a downhole plug in the subsurface completion string. The injection well string design will be finalised during the detailed design process, but fundamentally the planned CRA tubulars, downhole production casing isolation packer and the CRA wellhead provide the basis for a sound failsafe design.

14.1.4 All Well Operations

The CO_2 will remain contained within the wells during Operations based upon the existing process, industry standards and regulations for managing well integrity. Bridgeport applies these systems by its WIMS which honours the QLD Code of Practice (see Chapter 3). The aim of well head monitoring (see Chapter 5, Monitoring Plan and Schedule) is to validate that the injected CO_2 is contained within the formation and inside the PM well areas as modelled (no detectable leaks beyond allowable limits), and there is negligible risk of future CO_2 leakage, or formation fluid displacement which could have a negative impact on human health or the environment.

The wells’ casing, cement, wellheads and completion string will meet industry regulatory requirements (refer to Chapter 3 for full detail). As such it is unlikely that any CO_2 will escape the confines of the formation. However, to validate this regular CO_2 monitoring at the wellhead on the injection well and PM wells production casing annuli will be undertaken as is current practice in the BEL WIMS. A mass balance calculation, as detailed in the Chapter 5 Monitoring Plan, will also be used to detect anomalies.

14.1.4.1. Assessment of environmental impacts: Well Operations

During well Operations, surface and production casing annuli will be monitored to detect any adverse conditions above the thresholds developed in Chapter 5: Monitoring Plan and Schedule. Should CO_2 levels exceed the monitoring threshold limits, the affected well operation will be shut down, reassessed and depending on the type of incident, contingency plans detailed in Chapter 3 implemented.

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Chapter 15: Assessment of Impact: Noise

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15.0 Executive Summary

The following Chapter identifies and assesses potential noise generating sources or activities and details the mitigating controls that will be implemented to not exceed noise threshold values at any sensitive receptor. All activities will adopt the current PL1 Environmental Authority Noise Thresholds, the Bridgeport Noise Management Procedure and EMP requirements (both documents reflect the commitments within the current PL1 Environmental Authority).

The Moonie Oil Field is located in a rural-mixed cropping district, some distance from any urban centre. The closest potential noise receptor is at the Bridgeport accommodation block and facilities, 400m from the proposed injection site. Given the application of the Bridgeport Energy Noise Management Procedures, the potential of a noise impact to the receiving environment is assessed as being negligible. And in any event the nearest home is 2km distant from the site.

Overpage, the existing PL1 Noise Environmental Authority conditions are considered in the light of the proposed initial injection project activities.

15.1 Introduction

Table 15-1 lists the current PL1 Environmental Authority Noise conditions at the noise receptor.

Table 15-1, PL1 EA Noise Nuisance Limits

Schedule D, Table 1 – Noise Nuisance Limits

Time Period	Metric	Short Term Noise Event	Medium Term Noise Event	Long Term Noise Event
7:00 am – 6:00 pm	$L_{Aeq,adj,15\ min}$	45 dBA	43 dBA	40 dBA
6:00 pm – 10:00 pm	$L_{Aeq,adj,15\ min}$	40 dBA	38 dBA	35 dBA
10:00 pm – 6:00 am	$L_{Aeq,adj,15\ min}$	28 dBA	28 dBA	28 dBA
	Max $L_{pA,\ 15\ mins}$	55 dBA	55 dBA	55 dBA
6:00 am – 7:00 am	$L_{Aeq,adj,15\ min}$	40 dBA	38 dBA	35 dBA

1. The noise limits in Table 1 have been set based on the following deemed **background noise levels** (L_{ABG}):
7:00am—6:00 pm: 35 dBA
6:00pm—10:00 pm: 30 dBA
10:00pm—6:00 am: 25 dBA
6:00am—7:00 am: 30 dBA

(D3) Notwithstanding condition (D1), emission of any low frequency noise must not exceed either (D3(a)) and (D3(b)), or (D3(c)) and (D3(d)) in the event of a **valid complaint** about low frequency noise being made to the administering authority:

(a) 60 dB(C) measured outside the **sensitive receptor**; and

(b) the difference between the external A-weighted and C-weighted noise levels is no greater than 20 dB; or

(c) 50 dB(Z) measured inside the sensitive receptor; and

(d) the difference between the internal A-weighted and Z-weighted (Max $L_{pZ,\ 15\ min}$) noise levels is no greater than 15 dB.

15.2 Assessment of environmental impacts: Noise

Table 15-2 below illustrates the EA Noise assessments related to the proposed amendment activities.

Table 15-2, Assessment of the Proposed Amendment Activities regarding Noise and Noise Controls

Petroleum Activity	Lowest Applicable EA Limit at Receptor	Suggested Setback distance from a potential impact zone to meet limit (m)	Assessment of key management strategies
Construction CO_2 Infrastructure	40dB	150	Adoption of the Bridgeport Noise Management Procedure and EMP, Notification of activity to Landholders,
Rig Workover (Swap out of Tubulars)	40dB	150	Swap out of downhole tubulars is estimated to take up to 96 hours and may operate for relatively short periods, will not involve any drilling and will be during daylight hours. No historic complaints about previous drilling or workover operations. Key drilling noise management strategies: - adoption of the Bridgeport Noise Management Procedure - notification to landholders
Receival of CO_2	7am to 6pm 40dB 6pm -10pm 35dB 10pm to 6am 28dB	150	Receival of CO_2 will be occasional deliveries on a 24-hour basis, the objective is to arrange receivals between 6am to 7pm, however deliveries may occur outside this time based on production criteria.
Operation of CO_2 plant	7am to 6pm 40dB 6pm -10pm 35dB 10pm to 6am 28dB	150	The injection of CO_2 will be on an automated basis over 24 hours

The closest receptor is the Moonie Oil Field accommodation unit and its offices located within 400 m of the proposed activity. The closest landowner sensitive receptor is located greater than 2 km from the proposed activity.

15.3 Assessment of environmental impacts: noise

The assessment concludes that the distance from the noise generation source and the closest potential noise receptor is 400 m. As noise dissipates at the square of the distance from the noise source, noise received at the closest receptor will be below the noise thresholds detailed in the current environmental licence (EA) as detailed above. In addition, the Bridgeport Noise Control Procedure and the Bridgeport EMP will be implemented on site.

Should a noise complaint be raised, however, it will be investigated and actions to mitigate the noise will be undertaken.

There are no vibration or blast impacts resulting from this proposed amendment.

In summary, no adverse impacts concerning noise emissions or vibration are expected.

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Chapter 16: Assessment of Impact: Terrestrial Ecology

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16.0 Executive Summary

This Chapter assesses potential impact to Terrestrial Ecology. This topic assesses,

- Environmentally Sensitive Areas (ESAs),
- Threatened species,
- Weeds and pests,
- Feral animals,
- Implementation of bio-security measures and controls, and
- Surface waters, and chemical use and storage.

The assessment is, there will be no impact on Terrestrial Ecology due to,

- the small footprint of the initial injection project,
- the project will be implemented on a brownfield site with existing infrastructure,
- historical ongoing agricultural practices have cleared the land of any remnant vegetation of significance within 3 km of the site,
- There are no sensitive environmental areas within the project footprint,
- There are no threatened species within the project footprint,
- the existing checks and balances implemented through the Bridgeport Energy EMS, and
- There are no surface waters impacted by this project.

16.1 Introduction

Most of PL 1 lease is primary agriculture production area with minor areas of classified "non-remnant" vegetation. The area is interspersed with traces of "remnant vegetation" mainly located along fence lines and stock routes. Some of the habitat that does intersperse with the "non-remnant" farmland immediately surrounding the field is classified as "least concern" (Vegetation Management Act) and "no concern at present" (biodiversity status), and includes primarily Eucalyptus species, specifically, *Eucalyptus chloroclada*, *Callitris glaucophylla, C. endlicheri, Angophora leiocarpa* woodland (See Table 16-1, and Figure 16.1 overpage).

Clark (*et al*) estimates 24,725 hectares (or 38%) of the Moonie River basin has been cleared since the start of European occupation resulting in the gross removal of native vegetation replaced by agriculture cropping and mixed farming activities.

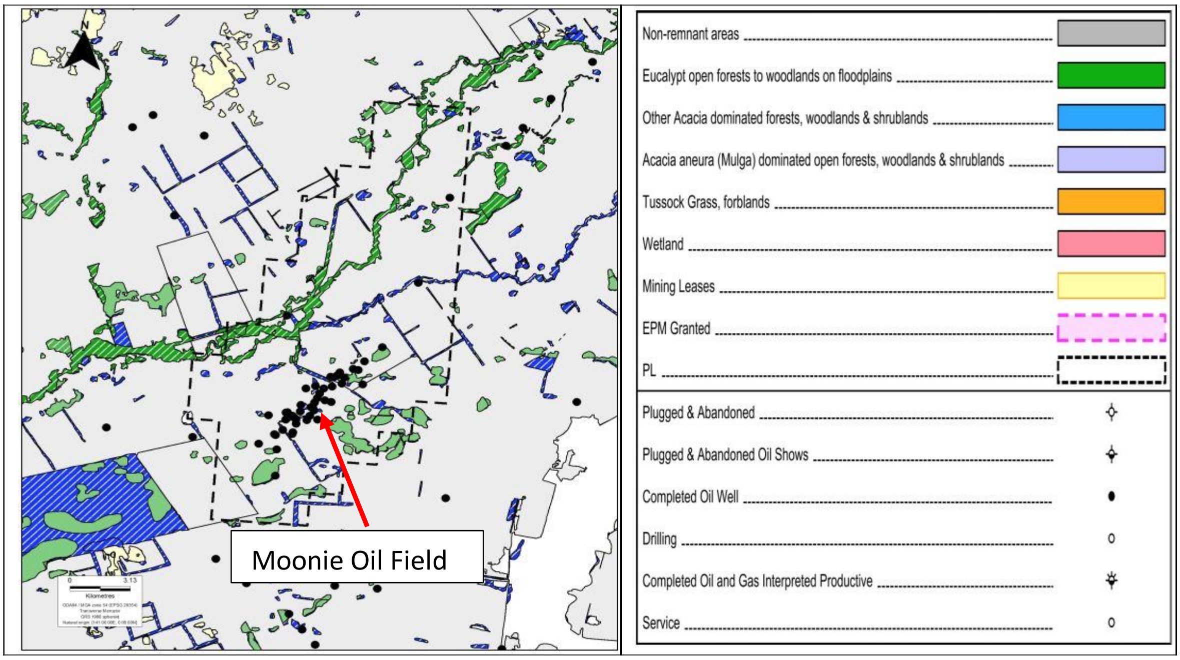
Several of the habitats across the Basin have "of concern" or "endangered biodiversity status". This include *Eucalyptus populnea* woodland, which occur in a small area in the northeast of the tenement boundary. The "closest of concern/endangered biodiversity status habitat" nearest the facility is *Acacia harpophylla* and *Casuarina cristata* shrubby open forest and *E. populnea*, in a thin boundary scattered over farmland and bordering a road and fence line some kilometres from the project. The most abundant "of concern / endangered biodiversity status" within the tenement boundary occurs away from petroleum activities, running west to northeast, and including E*. populnea, E. tereticornis or E. camaldulensis* woodland (see Figure 16.2, PL 1 sensitive areas). The "of concern" and "endangered habitat" is distinguished by a white hashed line over the habitat colour in the key.

As these special areas have been previously cleared, the proposed amendment will not impact on these special areas.

Table 16-1, A detailed summary of each regional ecosystem in PL 1.

Vegetation Group (BVG)	Regional Ecosystem (RE)	Short Description	Vegetation Management Act Class	Biodiversity Status
17a	11.3.2/11.3.17	Eucalyptuspopulnea woodland on alluvial plains	Of concern	Of concern/ Endangered
	11.3.25/11.3.27b,	Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines	Least concern,	Of concern
17b	11.3.2/11.3.17	Eucalyptus populnea woodland on alluvial plains	Of concern	Of concern/ Endangered
18b	11.5.4	Eucalyptus chloroclada, Callitris glaucophylla, C. endlicheri, Angophora leiocarpa woodland on Cainozoic sand plains	Least concern	No concern at present
25a	11.4.3 11.4.3/11.3.2 11.3.17	Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains Eucalyptus populnea woodland on alluvial plains Eucalyptus populnea woodland with Acacia harpophylla and/or Casuarina cristata on alluvial plains	Endangered Endangered Of concern	Endangered Of concern Endangered

Figure 16-1, a Plot of Remnant Vegetation in the local region



16.2 Environmentally Sensitive Areas[1]

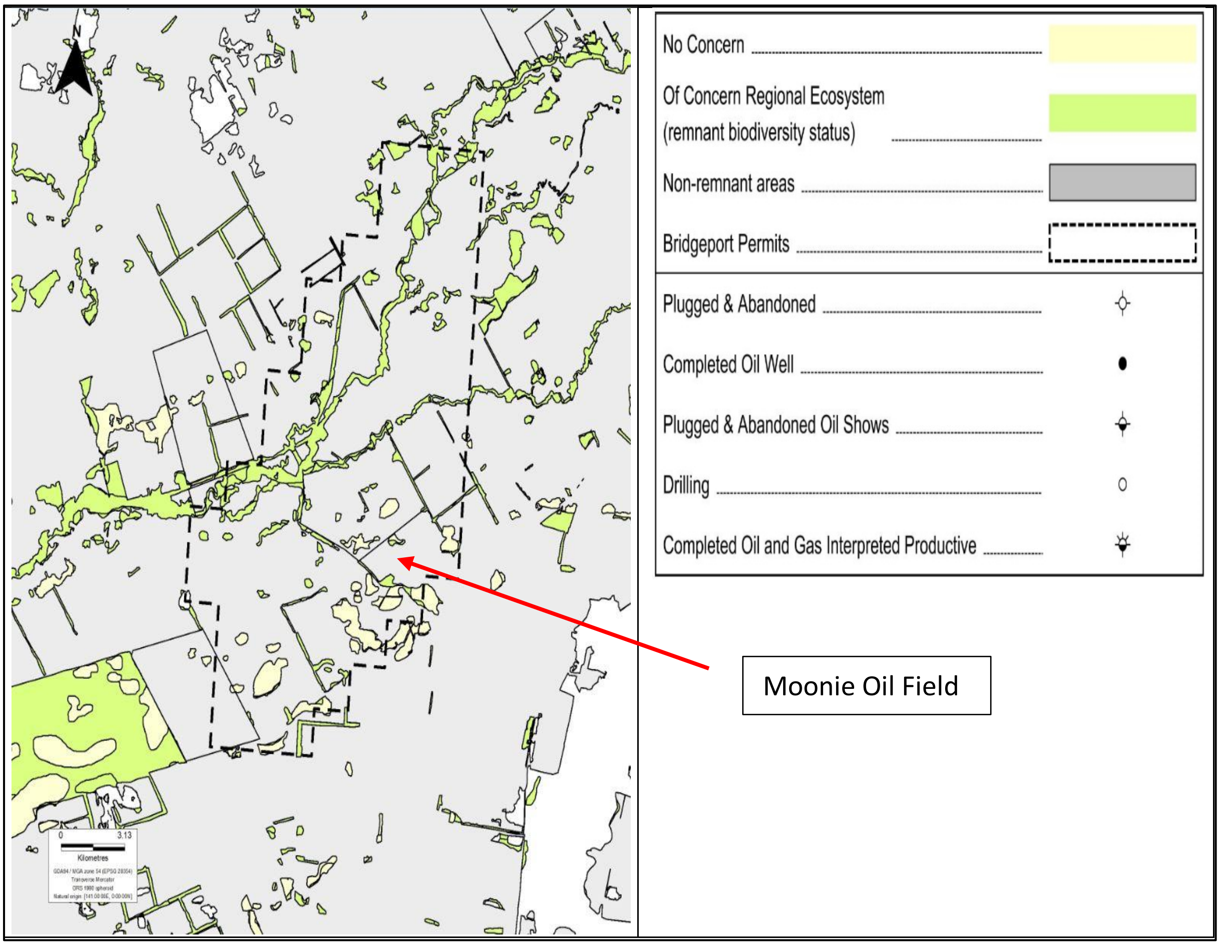
“Environmentally sensitive areas” as illustrated above are determined by the State of Queensland. These areas are overlaid against a plot of Bridgeport Energy tenement (PL1 in the Figure 16-2). There is one defined environmentally sensitive area across all Bridgeport Energy tenements, including PL 1 Moonie, a regional ecosystem known as “remnant vegetation”. “Remnant vegetation” is defined by being 10-30 % of its pre-clearing extent across the bioregion or more than 30 % of its pre-clearing extent remains and the remnant extent is less than 100 km^2. In addition to the “remnant vegetation” category, under the EP Act (1994), the category can be deemed ‘of concern’ if 10-30 % of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss. The only remnant regional ecosystem mapped near or within the PL 1 Moonie Bridgeport tenement listed as “of concern” are areas along some fence lines. The PL 1 Moonie tenement is in primary cropping land. There are no significant watercourses, wetlands, groundwater dependent ecosystems or springs located within the PL 1 Moonie tenement.

[1] *This geospatial information was accessed from the Queensland Spatial Catalogue on 11/03/2019 [http://qldspatial.information.qld.gov.au/catalogue].*

16.2.1 Environmental Assessment: Sensitive Areas

No adverse impact will occur to environmentally sensitive areas.

Figure 16-2, Regional Environmentally Sensitive Areas



This geospatial information was accessed from the Queensland Spatial Catalogue on 11/03/2019 [http://qldspatial.information.qld.gov.au/catalogue].

16.3 Threatened Species [2]

Due to the extensive degree of historical previous clearing and agricultural practices there has been no record of the presence of any threatened species on PL 1. Using the Australian Governments Protected Matters Search Tool (the Tool), a radius was extended from a central coordinate within the tenement to cover all boundary edges to create the search area. The tool provides details on all matters of national environmental significance overlapping the user defined search area. This includes threatened species, and those listed under the Environmental Protection and Biodiversity Conservation Act (1999). The tool lists all matter which “may occur in, or may relate to” the search area, so this resource is indicative only.

Regarding threatened species, the tool compares the search area to known distribution ranges for each species, categorised as “Species or species habitat likely to occur” and “Species or species habitat may occur” within the search area. The species listed below may or may not occur within Bridgeport Energy PL1 tenement. Threatened species and their status under the Environment Protection & Biodiversity Conservation Act (1999) (EPBC Act 1999).

From this study, six species whose distribution is mapped as occurring over PL 1 Moonie, including five bird species, one mammal and one plant. None of these species has been physically recorded or sighted on PL 1 Moonie.

16.3.1 Environmental Value & Objective

If sensitive vegetative classified areas exist on PL 1, these areas would be preserved under the Bridgeport EMP conditions.

16.3.2 Assessment of Terrestrial Ecology

Given the very small disturbance area (previously cleared and only 1 ha in area added to the existing well pad area), the relatively small nature of the pilot plant, and the fact that no clearing will occur as the area is already cleared, then “no adverse impact” is envisaged for any local flora or fauna. No additional vegetation clearing is planned or is part of this EA amended application.

[2] *This geospatial/distribution information was accessed from the Australian Governments Department of Environment and Energy’s Protected Matters Search Tool website on 11/03/2019 [http://www.environment.gov.au/webgis-framework/apps/pmst/pmst-coordinate.jsf] Nature Conservation Act 1992 (Qld) and the Nature Conservation (Wildlife) Regulation 2006 (QLD) (collectively: NC Act).*

16.4 Assessment of Weeds and Pests

The area is subject to impact from weeds and pests. It is a requirement of the Landholder Compensation Agreements and the Bridgeport EMP that vehicles travelling from or through a weed infested area undergo a weed inspection. If weeds are suspected of being present, then the vehicle or machine or both are required to be cleaned down and inspected again prior to ingress onto the target property. A Weed declaration form (Queensland Government) is currently completed prior to ingress onto the property.

16.4.1 Environmental Value & Objective: Weeds and Pests

The objective is to prevent the spread of weed and pests and if an outbreak could occur then to apply control measures to prevent and mitigate further impact. Table 16-2: Bridgeport Energy, lists regulated pests and weeds in the Moonie Area.

Eleven plants and twelve animals listed as regulated Biosecurity matters under the Biosecurity Act 2014 (Qld) are known or considered to potentially occur within the Project area (Figure 16-2). Nine of the regulated plants are also listed as Weeds of National Significance (WONS). Six plants listed as regulated Biosecurity matters were identified in the Project area during the field surveys.

Table 16-2, A list of known weeds and feral animals in the region

Common name	Scientific name	Status/Source		
		Biosecurity Act	WONS 1	PM Search 2
Pest plants known to occur				
Parthenium Weed	Parthenium hysterophorus	Restricted Invasive	x	x
Tiger Pear	Opuntia aurantiaca	Restricted Invasive	x	
Prickly Pear	Opuntia stricta	Restricted Invasive	x	
Velvety Tree Pear	Opuntia tomentosa	Restricted Invasive	x	
Harrisia Cactus	Harrisia martinii	Restricted		
Invasive Mother of Millions	Bryophyllum delagoense	Restricted Invasive		
Parkinsonia	Parkinsonia aculeata	Restricted Invasive		
African Boxthorn	Lycium ferocissimum	Restricted Invasive		

Common name	Scientific name	Status/Source		
		Biosecurity Act	WONS 1	PM Search 2
Pest plants known to occur				
Groundsel	Baccharis halimifolia			
Cats Claw Creeper	Macfadyena unguis-cati			
Desert verbena	Glandularia aristigera			
Pest plants considered potential to occur				
Prickly Acacia	Acacia nilotica	Restricted Invasive	x	x
Pest animals Known to Occur				
Dingo (wild dog0	Canis lupus dingo/familaris	Restricted Invasive		x
Feral Cat	Felis catus	Restricted Invasive		x
Rabbit	Oryctolagus cuniculus	Restricted Invasive		x
Feral Pig	Sus scrofa	Restricted Invasive		x
Feral Horse	Equus caballus	Other invasive animal		x
House Mouse	Mus musculus	Other invasive animal		x
Asian House Gecko	Gecko Hemidactylus frenatus	Other invasive animal		x
Pest animals with potential to occur				
Red Fox	Vulpes vulpes	Restricted Invasive		x

1 Weeds of National Security,

2PM- Search – Species highlighted in the EPBC Act Protected Matters search tool

16.4.2 Assessment of environmental impacts: Weeds and Noxious plants

The proliferation of weed species in the landscape can have a serious effect on biodiversity values and ecosystem function. In general, weed infestation levels across the Project area are low. The weeds currently observed to be causing the most notable ecological nuisance are Opuntia spp. including prickly pear, tree pear and tiger pear.

Harrisia cactus, while not currently a widespread problem in the Project area, has the potential to spread following disturbance, particularly on Land Zone 9, and inhibit regeneration processes.

Mother of millions *(Byrophyllum daigremontianin*) has also been detected in the area and can be in linear remnants following disturbance, such as along roadsides and drainage features.
Although not declared as an environmental or listed weed species, the encroachment of exotic grasses such as buffel grass (*Cenchrus ciliaris*) and green panic (*Panicum maximum var. trichoglume*) into natural vegetation communities of the Project area has the potential to degrade habitat condition both directly and through their influence on fire intensity and frequency. Much of the area has already been affected by the spread of buffel grass.

16.5 Feral Animals

Cat, rabbit, feral pig, red fox and cane toad are of importance within the Project area due to their potential to negatively impact on native species and their habitat. It is unlikely that these species would be spread via vehicular movement associated with the Project.

Feral Animals will continue to be managed as per the Bridgeport Environmental Management Policy, which minimizes the risks associated with feral animals. The Bridgeport EMP describes mandatory requirements, defines clear roles and responsibilities, as well as practical measures in relation to feral animal control.

16.5.1 Management Practices

Management practices for controlling pests and weeds, noxious plants and feral animals are outlined in Bridgeport EMP. The EMP describes mandatory requirements in minimising the risks associated with invasive plants and animals. It defines clear roles and responsibilities, and outlines practical control measures, in relation to weeds, noxious plants and feral animals.

16.5.2 Objectives

- No introduction of new invasive or legislated biosecurity matter (including flora and fauna) as a result of petroleum activities,
- No spread of invasive or legislated biosecurity matter (including flora and fauna) as a result of petroleum activities within or between properties, and
- No breaches of biosecurity related land access rules.

16.6 Implementation Strategy Biosecurity Risk Management

The following represents the Bridgeport' Biosecurity Risk Management Program.

16.6.1 Pests and Weeds - Vehicle and Machinery Movements

Mandatory wash down and inspection frequencies for Pest and Weed control if travelling from a risk declared area or where known noxious weeds are present (see Pest and Weed Management Procedure for trigger values). This wash down and inspection frequency, nominated for each risk category, is designed to set minimum standards for wash down and inspection and ensure that inspections will occur in a scheduled manner, at an increased frequency for higher risk activities.

16.6.2 Pest Animals – Proliferation and Spread

The risk of pest animal spread, and proliferation will be mitigated by reducing the likelihood of animals consuming food and other edible waste products through effective waste management; minimising habitats suitable for pest animal breeding by maintaining clean and tidy worksites, undertaking monitoring for pest animals and undertaking pest control where necessary.

16.6.3 Authority to Work

Biosecurity constraints and requirements for specific scopes of work are based on stakeholder engagement and ecological surveys. Ecological surveys and mapping of populations of legislated and invasive plant matter is conducted at or before pre-clearance on infrastructure areas or pre-clearance of entire landholder property if negotiated by landholder.

16.6.4 Accessing Land

Land access rules are mandatory for all personnel accessing the Moonie production facility and are the primary method for communicating biosecurity hazards located on the property. The specific property access rules will outline:

wash down requirements,

vehicles avoidance of hazards and

what actions are required when vehicles/ machines leave the property and/or move between landholder areas

16.6.5 Construction & Civil Maintenance/Works Control Management

Contractors and businesses are required to:

- develop an Environmental Management Plan (or equivalent) for the specific scope of works,
- document the controls to manage risk, and
- any biosecurity risks with reference to Access to Work, Land Access Rules, and the operations.

16.6.6 Biosecurity Procedure. Controls must include:

- hygiene of vehicles/machinery,
- entering land and transporting,
- vehicle management; and
- management or treatment (mechanical or chemical) of infestations prior to or during works; wash down locations and inspections.

16.6.7 Evaluation & Assurance - Wash Down Standards

The process of washing down reduces the risk of spreading biosecurity matter. The expectation is that following wash down and inspection, the machine / vehicle is free of things capable of carrying weed seed, pathogens, diseases, or animal pests. While a vehicle hygiene “wash down”, and inspection cannot guarantee that a vehicle / machine or attachment item is completely free of Biosecurity matter, all reasonable effort must be made to achieve that target. This includes accessing all areas indicated on the inspection report and which: are hidden from view; accessed only by removing plates, guards, and covers and contain tools, equipment, and attachments.

The vehicle / machine once washed and inspected, is considered clean only at the time of completing the inspection. From then on, the vehicle cleanliness remains the responsibility of the operator of the vehicle / machine and will depend on the surface being driven on, route taken, and work area accessed.

16.6.8 Assessment of environmental impacts: Weeds and Pests

By implementing the environmental controls detailed above any adverse environmental impacts caused by weeds, noxious plants and pests (feral animals) will be controlled and reduced.

16.7 Assessment of Surface Waters

16.7.1 Introduction

The proposed amendment project is located in the catchment of the Moonie River. Local overland flow is towards nearby ephemeral and intermittent streams (Toombilla and Middle Creeks). Agricultural activities (clearing vegetation, grazing density, and cropping cycles) are recognised by DPIRM 1995, as causing erosion and sedimentation in the immediate area which in turn has impacted stream flow intensity, water quality and aquatic habitat all of which are in poor condition[3]

16.7.2 Wetlands

The area does not contain any wetlands as defined by the ANZECC Wetlands Network (1994). However, it is in an area defined by the regional Water Management Plan as being of medium importance.

16.7.3 Springs

No springs or Groundwater Dependent Ecosystems (GDEs) have been found in the immediate area. Groundwater dependent ecosystems which require access to groundwater either intermittently or permanently and may vary over time and location. Given the nature of the activity being limited to deep oil reservoirs, GDEs that rely on shallow groundwater are not considered relevant to this assessment.

16.7.4 Flooding

The entire local region is subject to infrequent flooding; however, this will not impact infrastructure as it is not impacted by water.

[3] *The State of the Rivers: Dawson River and Major Tributaries Report (Department of Primary Industries Resource Management, 1995)*

16.7.5 Environmental Value & Objective

The objective is to avoid the increase of erosion and sediment controls in an already disturbed area, which will protect environmental values.

16.7.6 Assessment of Environmental Impacts: Surface Waters

The proposed amendment will have negligible impact on surface waters. Where required, appropriate land stabilisation and erosion prevention measures will be put in place. Where this occurs, proposed activities are not considered to have a significant or adverse impact on conservation values.

16.8 Chemicals and fuel storage areas (if any) will be bunded.

- Routine visual inspection will be undertaken to confirm erosion and sediment controls are adequate.
- Erosion and sediment controls will be implemented to control surface waters entering and leaving the proposed site.

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 17: Assessment of Impact: Waste

Commercial in Confidence

Moonie Injection Well 27 (M27)

Contents

17.0 Summary

All wastes will be managed by the site-based Waste Management Plan, which is a segment of the Bridgeport Energy EMP. Through the implementation of the BEL Waste Management Procedure, no adverse impacts related to waste are expected.

17.1 Assessment of Impact: Waste Management

By its very nature, this initial CO_2 injection project is a waste management project on a massive scale, whereby CO_2, that otherwise would have been discharged to the atmosphere is being captured and sequestered, therefore preventing its entry into the atmosphere.

On site at the Moonie Oil Field, all waste streams generated by Bridgeport activities are first assessed by management using the site-based Bridgeport Waste Management Procedure. This procedure is compliant with and based on the Policies and Acts, and Regulations of the Queensland & Local governments (i.e., Environmental Protection Act & Regulations, the Waste Reduction and Recycling Act and Regulations waste reduction initiatives, and the Local Government Waste Management Reforms).

All waste generated by construction and operation of the proposal will be managed through the application of the Bridgeport Waste Management Procedure. No adverse impacts are expected.

17.2 Environmental Value and Objective

The intent is to not create an environmental impact by not managing the waste as required in the conditions listed in the Environmental Authority.

All wastes are characterised, grouped and managed according to the class of waste presented and managed using the Bridgeport Waste Management Plan. Regulated waste is removed to a licensed facility using a trackable process and DES licensed waste operators.

17.3 Assessment of environmental impacts: Waste Management

Potential waste related impacts should be minimal (if any) as all wastes are managed using the Bridgeport Waste Management Procedure.

The wastes managed by the Bridgeport Energy waste management plan includes;

- general housekeeping, and
- wastes brought to site such as packaging.

Assurance and validation of waste management will be by routine inspection and audit, and any complaints would be registered and investigated in accordance with the EMP.

Through the implementation of the BEL Waste Management Procedure, no adverse impacts related to waste are expected.

Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 18: Assessment of Impact: Community & Economic Benefit

Commercial in Confidence

Monnie Injection Well 27 (M27)

Contents

18.0 Executive Summary

Engagement with key stakeholders and the local community is required to:

- Explain the Initial Project Plan,
- Inform about the nature of the benefits and trade-offs with the establishment of the Moonie large scale CCS hub,
- Set the context for transferring to the long-term decarbonisation of the energy sector (power stations and large carbon producing Industry),
- Maintaining dialogue about carbon sequestration reducing atmospheric emissions, as the project rolls out, and
- By sequestering CO_2 enhance the long-term maintenance of existing power producing infrastructure and local mines and jobs.

The Economic Benefit to the people of Queensland,

- Continued oil production (1.5m barrels) generating royalty payments to the State, economic multiplier effect on local employment from the project development investment of $15m, and at the same time sequestering 960,000 tonnes of CO_2.

18.1 Key factors and messages

- There are no sensitive receptors within the project area that will be impacted by the proposed activities.
- The proposed amendment project will be established on the Moonie oilfield site, a brownfields site which contains existing disturbed areas, has been in production for fifty years and as such is not expected to have any impact on non-indigenous artefacts. Bridgeport has procedures in place (the Bridgeport EMS and Production EMP) to manage unexpected events and other procedures that manage issues such as noise, dust, and air emissions.
- There will be considerable advantage to the greater community and the environment in general, through sequestration of CO_2, extension of the producing life of the Moonie field and continuation of jobs in the area as a result of this project.

18.2 Economic Benefit

There's considerable benefit to Queensland for approving this amendment, including the following economic benefits,

- The environmental value of sequestering 920,000 tonnes of CO_2,

- Depending on the ultimate regulatory approval, available supply volume and efficiency of the proposed first stage CO_2 injection into the Moonie oil field, Bridgeport expects that 1.5 million barrels of otherwise unproducible oil may deliver approximately $12 million of additional royalties to the state of Queensland over the economic life of the field. In turn, Bridgeport's circa $15 million capital investment, in conjunction with the $150 million being spent by CTSCo to build the industrial scale post combustion capture plant at the Milmerran power plant in the proposed first stage project can be expected to stimulate the local economy through employment of many construction and operating personnel on the projects.

- Should this injection project prove successful, Bridgeport expects a further incremental 6.4 million barrels with corresponding increased state royalty payments, through increasing to 1 MM mT per annum with a scaled-up PCC plant at Milmerran capturing significantly more CO_2 for the project.

- Continued domestic oi production refined in Australia assisting with domestic security of supply, and

- Continued employment of the Moonie Oil Field staff, new personnel for the construction, commissioning and operating phase and the subsequent income multiplier effect to the local area and region.

18.3 Assessment of Community

A local Community Consultation Plan will be created to engage the local and greater community by providing information for the local landholder and traditional landholders. The information will include the validation of well integrity, project up-dates and a mechanism to answer information requests and concerns raised.

Together with the current petroleum extraction project, the local area comprises mixed rural enterprises including cropping- irrigated and dryland, cattle, and other livestock. The proposed CO_2 project will be located within the existing oil production area and the surrounding farming operations. In the greater region the project is surrounded by coal seam gas operations and some mining operations.

All the land in the local area is freehold inter-dispersed with a network of stock routes and roads. The freehold land is held by Bridgeport Energy, small scale farmers and rural enterprises, CSG companies, petroleum companies. Within the freehold area there are farming homesteads which are located some distance from the proposed operations. There are 5 homesteads within the tenement area and one within the proposed amendment area.

The closest population centre is the Moonie Township, at the junction of the Leichardt and Moonie Highways. It is a truck stop centre for the surrounding region. Further afield are the more urban centres including the towns of Tara, Dalby, Chinchilla and Goondiwindi.

The local Government stakeholders include Western Downs Regional Council, and the Goondiwindi Regional Council, and offices related to various State Government Departments.

18.4 A Targeted Communication Approach

Engagement via community hall discussions of the project will be held with;

- Local stakeholders,
- Local landholders,
- Local mine and power station works,
- Local schools, and
- Politicians, policy makers, journalists, and financiers.

18.5 Native Title

There is currently one registered Native Title claim over the project area. An ILUA (Indigenous Land Use Agreement) with Bridgeport energy is in place. The ILUA agreement allows the Native Title holder to plan, investigate, monitor and access all lands within the project area. No impact to indigenous artefacts and culture at Moonie 27 are predicted for the pilot project as the entire area has been previously disturbed and culturally surveyed.

18.6 Non-Indigenous Heritage sites

The Moonie Oil Field infrastructure (being the first oil production site in Australia) is a heritage site and contains exploration and development sites such as derelict homesteads, exploration artefacts, stock routes, surveyor marked trees, and remnant boundary fences. None of the project activities will impact these elements.

18.7 Assessment of Local Community

It is envisaged the proposed amendment (given the small size of the activity) will have limited (if any) impact on local employment as the CO_2 injection and sequestration process is no different to current operations. CO_2 delivery, storage, injection, and monitoring will be adsorbed within the existing workforce. There will be no impact on population, accommodation, or local services.

Traffic impacts will be minimal as the trucking operations will be infrequent compared to other trucking operations in the district. No excessive dust or noise impacts are predicted from the construction or operations of the proposed amendment.

During school hours, several school bus routes use the following local roads which will be used by project traffic both the Leichardt and Moonie Highways to the local primary school and high schools at the larger centres. Bridgeport will notify trucking companies of the need for extra care during school transit times.

18.8 Assessment of environmental impacts: Community and Cultural Heritage

18.8.1 Community

There are no sensitive receptors within the project area that will be impacted by the proposed activities.

The proposed amendment project will be established on already disturbed areas and as such is not expected to have any impact on non-indigenous artefacts.

Bridgeport has procedures in place to manage unexpected events (the Bridgeport EMS and Production EMP) and several procedures that manage issues such as noise, dust, and air emissions.

There will be considerable advantage to the greater community and the environment in general, for the sequestering of CO_2 as a result of this project.

18.8.2 Native Title and Cultural Heritage

The area is already disturbed and has previously been culturally surveyed. The proposed amendment activities are not expected to have any further impact. Bridgeport has procedures in place to manage unexpected events related to say accidental discovery of Native Title related artefacts (see Bridgeport Native Title Procedure).